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A Technique for the Bloodstream Injection of Insects and its Application in Tests of Certain Insecticides[1]

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In connection with investigations under the direction of the late Dr. T. J. Headlee it became necessary to establish a testing procedure suitable for the survey of large numbers of materials for insecticidal activity. A review of the known methods for such investigations revealed that, in general, they consisted of the determination of contact or stomach action, or both, against one or more species of insects. The disadvantages of such surveys have since been discussed fully by Roark (1942). If few species are used materials of high specific or broad activity may be overlooked because of a specific lack of toxicity to the test species. The use of larger numbers of species is limited by the impracticability of maintaining a sufficiently representative number of test species under laboratory conditions throughout the year.

It was the firm belief of Dr. Headlee that that specificity of action of insecticides among species of insects was more closely associated with penetration than any other single factor. He was convinced that any proven insecticide which failed to show toxicity to certain species would be toxic to this species if it were possible for it to penetrate to the site of toxic action in the insect body. He reasoned that the principal barrier preventing a toxic agent from reaching its site of action was the insect integument in the case of contact applications and the wall of the alimentary tract in the case of stomach applications. His contention was that, if toxic agents could be placed beyond these barriers in evaluation tests, the major cause of specificity of action among species would be removed, and as a consequence it would be possible to depend on a single or limited number of species in an insecticidal survey with greater confidence that potentially active materials would not be overlooked. He further reasoned that the surest method of placing toxic agents within the insect body beyond these barriers would be that of injection to deposit the toxicant directly into the coelom to be distributed to its site of toxic action by the blood.

As early as 1936 Dr. Headlee urged the senior author to undertake the investigation of bloodstream injection of insects as a means of survey for new insecticides. It was not until 1939, however, when the establishment of an industrial research fellowship[4] with the senior author as fellow required the consideration of survey test methods, that active consideration was given to the possibilities of this test method. Later in the same year another industrial research fellowship[5] was established with the junior author as the fellow. As the work of this investigation also required consideration of survey test methods, the junior author joined in the exploration of the possibilities of this test and the subsequent development of an apparatus and technique for making such tests on a practicable and routine basis. The purpose of this paper is to set forth the technique developed through this joint effort, with data obtained in toxicity studies of recognized insecticides by this method with the American cockroach.

PREVIOUS USE OF THE BLOODSTREAM-INJECTION TECHNIQUE.—The bloodstream injection of insects has been used as a method of application of agents for toxicological and physiological study by a

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number of investigators. Michalsky (1905) made a study of the action of nicotine by injecting solutions of it under the integument of cockroaches. Shafer (1911) injected solutions of lead acetate and cadmium chloride into insects nearly dead from treatment with hydrogen sulfide in order to trace the penetration of the sulfide from the lead and cadmium precipitates formed. Crozier (1922) injected larvae of five species of Lepidoptera in studying their reactions to strychnine and atropine. Becker (1923) injected nicotine into the pericardial cavities, head ampullae, and intestines of grasshoppers. Campbell (1926) reported studies in which he compared the speed of toxic action of arsenic in silkworm larvae when injected into the bloodstream and when fed orally. Parfentjev & Devrient (1930) injected arsenic into the cockroach in studying its effect upon the respiratory processes. Campbell (1932) used the bloodstream injection of silkworm larvae and of grasshoppers in a study of the toxicity of a group of coal-tar dyes. Hockenyos & Lilly (1932) reported studies of the effects of the injection of nicotine into the bloodstream of the larva of a sphinx moth. Yeager *et al.* (1932) studied the physiological effects of various chemicals by injection into the bloodstream of the Oriental cockroach. Levine & Richardson (1934) studied the synergistic effect of certain salts on the paralytic action of nicotine by the bloodstream injection of American cockroaches. McIndoo (1937) made extensive studies of the effects of nicotine when injected into the bloodstream of adults and larvae of three species of blowflies, and larvae of the codling moth, silworm, and southern armyworm. Hockenyos (1939) used the bloodstream injection of the American cockroach in a study of the absorption of sodium fluoride by this insect. Ellisor (1936) and Richardson & Ellisor (1940) determined the effect of pH on the toxicity of nicotine injected into the bloodstream of the American cockroach. Cheng & Campbell (1940) injected American cockroaches with suspensions of phosphorus. Hansberry *et al.* (1940) made a study of the toxicity of nicotine by stomach and by bloodstream injections with larvae of four species of Lepidoptera. In two of the above listed works, Campbell (1932) and Yeager *et al.* (1932), the bloodstream injection was used for the survey of new insecticides. In both cases, however, the testing was limited to materials of a specific chemical group which was under investigation.

APPARATUS.—One of the major problems was the development of apparatus which would permit the rapid and accurate injection of insecticides without loss of blood. None of the methods used by previous workers appeared adequate. Shafer (1911), Crozier (1922), Hockenyos & Lilly (1932), Hockenyos (1939), and Cheng & Campbell (1940) used a standard hypodermic syringe and needle. This apparatus was not considered to be accurate enough for the needs of this investigation. McIndoo (1937) and Hansberry *et al.* (1940) used a micrometer-controlled syringe with hypodermic needle which had been described by Trevan (1922). This apparatus was rejected because of a basic criticism to which the authors felt it was subject. It was considered that the accuracy of this, or any device from which delivery is measured by the movement of the activating piston, could be affected markedly by factors influencing the delivery pressure, such as changes in the bore of the needle, clogging or partial clogging of the needle, injection into tissues instead of the coelom, or the use of solutions or suspensions of varying viscosity.

Campbell (1926, 1932) used for his injection a calibrated capillary tube on which was drawn a fine glass needle. He controlled the liquid in this pipette by varying the air pressure on the insecticide column through a tube leading to the operator's mouth. This apparatus, or some modification of it, was used by Yeager *et al.* (1932), Levine & Richardson (1934) and Ellisor (1936). It was felt that this apparatus gave the desired accuracy but that it could be improved by a stable mounting and the addition of a mechanical control for the air pressure. Such an apparatus would permit an accurate control of the flow of the insecticide in conjunction with an accurate measure of the actual amount of material delivered. An idea for the design of a suitable control mechanism was obtained from the observation of an apparatus in the laboratory of Dr. E. R. McGovran of the Bureau of Entomology and Plant quarantine at Beltsville, Maryland. This device has been described by McGovran

et al. (1940) as a micropipette for the measuring of small amounts of liquid insecticide onto the integument of insects. The delivery of the insecticide was regulated by a screw-controlled plunger. Using the principle of this device, an apparatus was designed, modifications of which proved to be satisfactory in most respects for the bloodstream injection of several species of insects.

The apparatus ultimately developed for this work consists of a micropipette mounted in a vertical position, the top of which is connected by a U-tube to a vertical glass tube in which a mercury column may be regulated in height by the manipulation of a screw-controlled plunger. The arrangement of this apparatus in shown in figure 1.

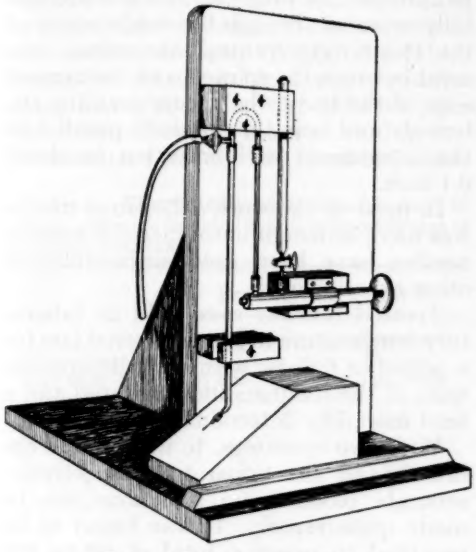

FIG. 1.—Injection Apparatus.

The micropipette is 18 inches long. Three-quarters of an inch from its lower end it is bent to give an angle of 30° from the horizontal. A joint to receive a hypodermic needle is ground on the lower tip. It has been found desirable to apply a film of vaseline on this joint to provide a tight seal. The pipette used most extensively in this work is designed to deliver a total volume of 0.2 cc. in 13 inches of its length which is graduated to measure in increments of 0.001 cc.

The U-tube connected to the top of the pipette is made of glass tubing of 0.1 inch bore. One arm of the U-tube is equipped with a side tube with stopcock. The mercury-column tube consists of a glass tube of 0.1 inch bore. It is joined to the U-tube at the top and to the control device at its lower end.

The pipettes and the U-tube were made to specification by laboratory supply companies.

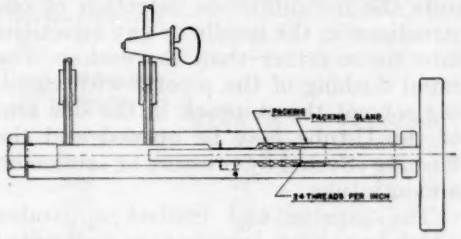

FIG. 2.—Detail of control device for injection apparatus.

The control device consists of a steel chamber into which operates a screw-controlled piston. Two openings from the chamber permit attachment to the mercury-column tube and the mercury reservoir, respectively. It was constructed to specification by a local machine shop. The detail of its construction is shown in figure 2. The piston is 0.25 inch in diameter and operates on a screw of a pitch of 24 threads per inch. Graphited packing cord has been found suitable for packing the piston to prevent the escape of the mercury.

All connections in the apparatus are made by collars of rubber tubing.

To give stability the whole apparatus is mounted on a vertical plank supported on a wide base. An important feature is the provision of a platform beneath the injection needle to serve as a support for the hand while holding the insect for injection. The upper surface of the platform is on the same angle from horizontal as the bent tip of the pipette. It is adjustable as to the perpendicular distance between its upper surface and the position of injection needle.

Mercury is introduced into the chamber and column to the desired height from the mercury reservoir for which a burette with stopcock is used. When he stopcock is closed the level of the mercury in the column becomes directly adjustable with the manipulation of the screw-controlled plunger.

The insecticide is drawn into the pipette through the needle by lowering the level of the mercury column. In injection

the insecticide is forced from the pipette by pressure exerted by raising the level of the mercury column and transmitted through the bridge of air between the two. This air bridge prevents any direct contact between the insecticide and the mercury column, and its compressibility permits the instantaneous detection of obstructions in the needle or any injections into tissue rather than the coelom. For rapid flushing of the pipette with cleaning solvent the stopcock in the side arm of the U-tube may be opened and the flushing effected by pressure or suction on a mouth tube.

The pipette and control apparatus which have been described are well suited for studies with insects weighing from 0.5 to 2 grams. For work with smaller insects more accurate injections might be possible with the use of smaller pipettes and a more sensitive control device.

Test Species.—The American cockroach, *Periplaneta americana* (L.), was selected as the most suitable species for this investigation. This was based on its large size and its availability as a laboratory-reared insect of uniform activity and resistance throughout the entire year. Adults of the age of nine months were used. They were obtained from a laboratory culture maintained by the techniques described by Heal (1948). Subsequent to the establishment of the test with the American cockroach the junior author utilized several other species, including adults of the squash bug, *Anasa tristris* (Deg)., adults of the Japanese beetle *Popillia japonica* (Newm.), larvae of the catalpa sphinx, *Ceratomia catalpae* (Bdvl.), and larvae of the silkworm, *Bombyx mori* (L.). This work has been reported previously (in a separate paper by Menusan).

TECHNIQUE.—For the purposes of rapid injection of large numbers of roaches without bleeding it was found necessary to immobilize the insects. This was effected by chilling. The roaches were transferred to chilled battery jars and placed in a refrigerator at 28 to 32°F. for 20 minutes. Under this refrigeration temperature they remained in a condition suitable for injection for a subsequent period of from 45 to 60 minutes. Experience showed that both under-chilled and over-chilled roaches tended to bleed somewhat on injection.

For testing, the roaches were segregated according to sex. Each individual was weighed to the nearest 0.1 g. and injected with a specified amount of the insecticidal preparation per 0.1 g. of body weight. Variation in dosage was effected by varying the concentration of the insecticide in the medium injected.

Injection has been made successfully through different parts in the insect integument. The senior author has used, exclusively, injection through the membrane between the head and prothroax as described by Hockenyos & Lilly (1932). By this procedure penetration is made at a point slightly to one side of the mid-dorsal line. The needle is directed caudally on a line parallel to the axis of the body and inserted to a depth of 0.125 to 0.2 inches. In addition the junior author has successfully injected through the conjunctiva of the third right ventral abdominal segment between the spiracle and the nearest edge of the body, the needle pointing anteriorly and being maintained parallel to the integument with insertion to about 0.1 inch.

In most of the work a 27-gauge needle was used, although both finer and coarser needles have been used successfully in other experiments.

Treated roaches were held at laboratory temperature in gauze-covered jars for a period of 6 days, with daily determinations of the numbers incapacitated and a final mortality determination.

With two operators, to manipulate the insects and the apparatus respectively, accurate bloodstream injections can be made quite rapidly. It was found to be practical to inject a total of 60 to 100 roaches using 6 to 10 different insecticidal solutions in an hour.

INJECTION MEDIA.—This technique was originally developed for use with insecticides which could be carried in an aqueous medium. Tests established that amounts of distilled water up to 0.01 ml. per 0.1 g. (100 ml./kg.) of body weight were tolerated by the roaches without producing mortality.

Investigation was made of the acceptability of some emulsifiers and water-miscible solvents as aids in carrying water-insoluble principles. These tests revealed that the following materials could be used in water solution in bloodstream injection without toxicity to the roach.

Ethyl alcohol	up to 4000 mg./kg. (e.g., 10% aqueous solution in the amount of 0.004 ml. per 0.1 g. body weight)
Acetone	up to 4000 mg./kg.
Methyl ethyl ketone	up to 2500 mg./kg.
Hydrochloric acid	up to 20 mg./kg. of N/10 concentration
Sodium oleate	up to 1000 mg./kg.
Potassium oleate	up to 400 mg./kg.
Alkyl aryl sodium sulfonate product[6]	up to 200 mg./kg.
Sodium lauryl sulfate[7]	up to 600 mg./kg.
Phthalic glycerol alkyl resin[8]	up to 17000 mg./kg.
Diethylene glycol dilaurate	up to 25000 mg./kg.

EFFECT OF CHILLING PERIOD ON INSECTICIDAL RESISTANCE.—Previous mention has been made of the optimum chilling period for injection without loss of blood. To determine the effect of chilling on insecticidal resistance, tests were made with sodium arsenate ($Na_2HAsO_4 \cdot 7H_2O$) injected at a uniform dosage into roaches which had been chilled for different periods of time from 15 minutes to 6 hours. The results of this test are given in table 1.

Table 1.—Effect of chilling period on toxicity of sodium arsenate injected into the bloodstream of American cockroach

Hours Chilled at 28.5° F.	Per Cent Mortality* Males Dosage 37.5 mg./kg.	Females Dosage 40 mg./kg.
½	49	38
1	22	44
2	35	23
4	61	41
6	55	68
	Not injected	
6	4	5

* 18 to 23 roaches used per point.

From these data it sppears that chilling periods of less than 4 hours have little, if any, effect on the resistance of roaches to sodium arsenate.

VOLUMES OF LIQUID INJECTED.—Although water could be injected without toxic effect in amounts up to 0.01 ml. per 0.1 g. of body weight, it was found that the difficulty in making injections without bleeding increased as the injected amount increased above 0.004 ml. per 0.1 g. Thus it was evident that the optimum amount for practical use of the test lay at or below this level. Studies were made with sodium arsenate and derris extractives to determine the influence of equal dosages of the insecticides in volumes varying from 0.0005 ml. up to 0.008 ml. per 0.1 g. The results of these tests are given in table 2. It appears that the specified dosages administered in the lowest volume of liquid did not produce as great a toxic effect as the same dosages administered in the larger volumes. This observation is in keeping with that of Hansberry *et al.* (1940) who found a segregation of small volumes of nicotine solutions when injected into the bloodstream of lepidopterous larvae, and with that of Hockenyos & Lilly (1932) who reported dilute solutions of nicotine to be more effective than more concentrated solutions when injected into the bloodstream of the larvae of *Celerio lineata*. There does not seem to be a significant difference among the effects obtained with equal dosages administered in volumes ranging from 0.001 ml. to 0.008 ml. per 0.1 g. On this evidence it was concluded that the optimum volume of insecticidal media

Table 2.—Effect of volume of insecticidal media injected into the bloodstream of the American cockroach with dosage of insecticidal principal constant.

Volume Injected ml. per 0.1 g.	Per Cent Mortality* Males	Females
Derris extractives (25% rotenone)	*24 mg./kg.*	*36 mg./kg.*
.0005	33	50
.001	42	67
.002	92	58
.004	50	75
.006	75	75
.008	75	67
Sodium arsenate	*30 mg./kg.*	*45 mg./kg.*
.0005	58	0
.001	67	12
.002	58	21
.004	33	42
.006	75	67
.008	50	42
	35 mg./kg.	
.001	92	—
.002	83	—
.004	67	—
.006	75	—
.008	58	—

* 12 to 24 roaches used per point.

[6] *Ultrawet*—The Atlantic Refining Company.
[7] *Orvus*—Proctor and Gamble Company.
[8] *Triton B-1956*—Rohm & Haas Company.

for use in this work was in the range of 0.002 ml. to 0.004 ml. per 0.1 g. of body weight.

OTHER USES FOR APPARATUS.—In conjunction with the establishment of the apparatus for use in bloodstream injection it became apparent that the same equipment could be used for other precision tests with insecticides. With a blunt needle it could be used to apply measured dosages of contact insecticides to the insect integument. It also was used by the junior author in oral feeding of measured amounts of stomach poisons. The senior author used the apparatus to inject measured amounts of stomach poisons directly into the crop of cockroaches passing through the integument, the coelom, and the crop wall. This last procedure was of doubtful value as a practical and accurate test as only about 50 per cent of the injections with female roaches were successful and a large number of the insects so treated rid themselves of their dosage by regurgitation.

TESTS WITH KNOWN INSECTICIDES.—In order to establish the validity of the bloodstream-injection test for determining potential insecticidal value, tests were made with several known insect toxicants. The results of the investigations of the junior author are the basis for the paper by Menusan (1948). The senior author conducted tests with five established toxicants: sodium arsenate ($Na_2HAsO_4 \cdot 7HO$), sodium fluoride (NaF), pyrethrins, nicotine alkaloid, and derris extractives (25 per cent rotenone), the results of which are given herewith.

Dosage/mortality curves were established by bloodstream injection for each material with both male and female adults of the American cockroach. To determine the stomach poison activity of the various toxicants against this species, tests were made by injection into the crop. As indicated previously, this test did not prove to be a practical one but it was possible to establish toxicity values for the various materials which are indicative of the approximate levels of activity. Contact tests also were made against the same species with each toxicant by a measured-drop technique using the injection apparatus for application of the solutions to the insect integument. In these determinations sodium arsenate and sodium fluoride were used in the form of aqueous solutions in all tests. Pyrethrins were prepared for bloodstream and stomach injection as aqueous suspensions prepared from alcoholic solutions so that the final preparation contained less than 10 per cent ethyl alcohol. For contact tests the pyrethrins were applied as an alcoholic solution. Nicotine alkaloid was injected for bloodstream and stomach tests as an aqueous solution while it was used in alcoholic solution for contact tests. Derris extractives were administered in bloodstream and stomach injections as an aqueous suspension prepared from acetone solution and containing less than 10 per cent acetone. Contact tests

Table 3.—Comparative toxicities of Insecticides to the American cockroach by bloodstream-injection, stomach-injection, and contact tests.

INSECTICIDE	SEX	APPROXIMATE L.D. 50 (MG./KG.) BY		
		Bloodstream Injection	Stomach Injection	Contact
Sodium arsenate	Female	42	500	>1600
	Male	25	<50	100
Sodium fluoride	Female	140	300–400	>2000
	Male	125	100–200	1200
Pyrethrins	Female	12.5	10 (probable)	3.25
	Male	1.75	4–6	1.5
Nicotine	Female	170	600–1000	800
	Male	80	200–400	225
Derris extractives (25% rotenone)	Female	30	>200	>8000 (L.D. 0)
	Male	20	125–250	8000

with derris were made with acetone solutions.

The values established by these tests are given in table 3. These data show that the injection test demonstrates the toxic value of the five established insecticides. Equal or higher toxicity was shown by this method in comparison with the stomach or contact tests in all cases except one. The recognized insectidical activity of derris extractives was not detectable in the contact test but was clearly demonstrated by the injection test presenting an example of a toxicant revealed through bloodstream tests that could be overlooked on the basis of a contact test. Although pyrethrins were more active by contact than by injection, both tests showed the material to be an outstanding toxicant.

When the bloodstream-injection test was undertaken it was felt that, because of the accuracy with which the test could be made, it might permit the relatively accurate establishment of dosage/mortality values with small numbers of insects at each dosage level. Experience with the test proved that this would be possible. As a test of this, toxicity values established in individual tests by both the the authors over a period of two years were compared. Such a comparison for bloodstream tests with sodium arsenate and derris extractives is shown in figures 3 and 4. The results of five tests, two conducted by one author and three by the other, are shown. The minimum number of roaches used per dosage was 3 and the maximum number 12. The uniformity of the dosage/mortality values established in these tests over a period of 2 years indicates the validity of the bloodstream test in determining the toxicity of insecticides with a relatively high degree of accuracy with small numbers of insects per dosage.

On the basis of this preliminary experience, it was concluded that the test was potentially useful in the survey of materials for insecticidal activity in that it provided a relatively accurate and rapid means for determining the comparative toxicities of compounds while using relatively small numbers of insects and eliminating, at least in part, the limitations of stomach and contact tests.

The method has been employed extensively at Rutgers University, since its establishment in 1940, in surveys for insecticides of both chemical and botanical origin.

SUMMARY.—An apparatus was designed for the injection of liquids into the bloodstream of insects for the purpose of

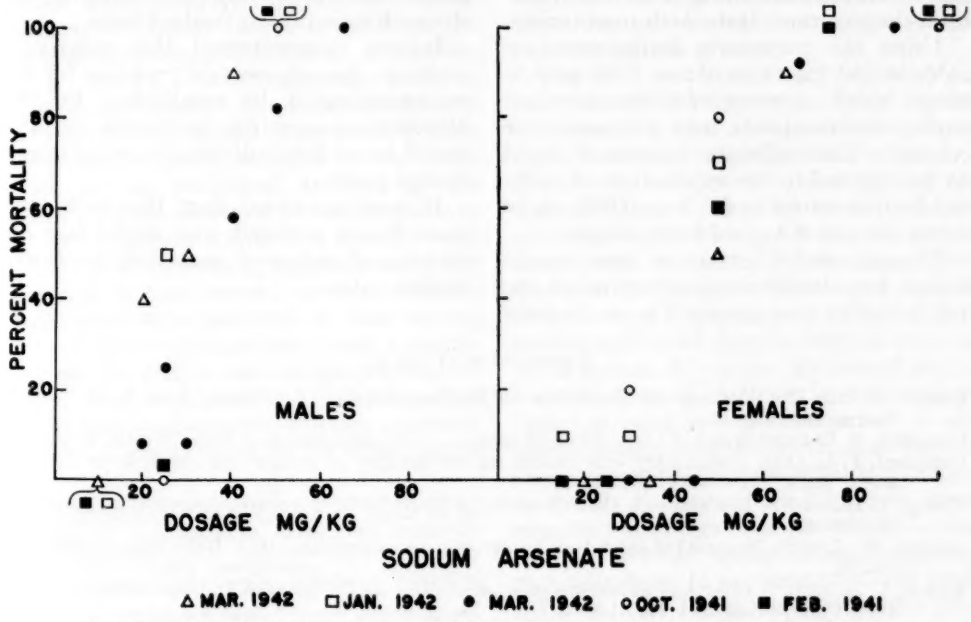

FIG. 3.—Dosage/mortality values established over a period of two years by bloodstream injection of the American cockroach using small numbers of insects.

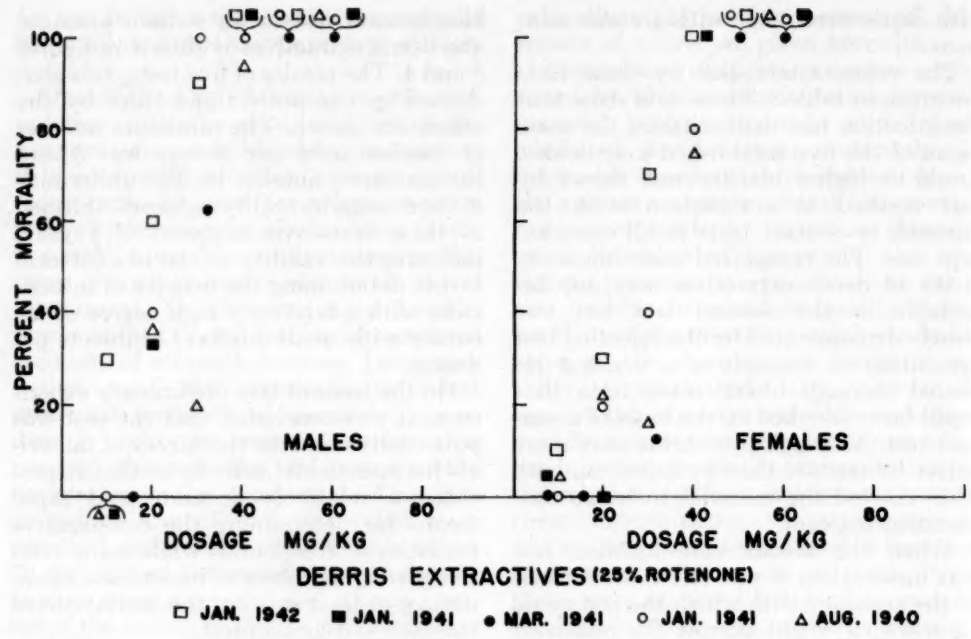

FIG. 4.—Dosage/mortality values established over a period of two years by bloodstream injection of the American cockroach using small numbers of insects.

the evaluation of insecticides. Using this equipment, a technique for the rapid and accurate injection of the American cockroach was developed. It was found that the apparatus also was suitable for making accurate oral-feeding tests and measured-drop contact tests with insecticides.

Using the cockroach, limits were established for injection of non-toxic quantities of water, aqueous solutions of certain surface-active agents, and water-miscible solvents. The optimum volume of liquid to be injected in the evaluation of insecticides was found to be from 0.002 ml. to 0.004 ml. per 0.1 g. of body weight.

Dosage/mortality curves were established by bloodstream injection of the roach for five insecticides. The toxicities of these compounds by injection were compared with their respective toxicities by stomach-injection and contact tests. It was found that the bloodstream test revealed the high toxic value of each compound, in general more positively than did either the stomach-injection or contact tests.

It was demonstrated that relatively accurate dosage/mortality values for insecticides could be established by the bloodstream-injection technique by the use of ten or less individual specimens per dosage point.

It was concluded that this technique provides an accurate and useful test for surveys of unknown materials for insecticidal value.

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Cotton Insect Control with Organic Insecticides[1,2]

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Individual fields and large, replicated plots were employed jointly in experiments on cotton insect control at the Edisto Experiment Station, Blackville, S. C., in 1947. An attempt was made to design and conduct the experiments in a manner which would approximate large scale, farm operations and at the same time permit statistical analysis of the data. Certain sacrifices had to be made in order to fashion a situation which would satisfy both demands. Approximately 260 acres of cotton located on two separate farm units were involved in these experiments. The replicated plots, each approximately 0.5 acre in size, occupied about 17 acres. The remainder of the acreage was in fields of various sizes. Further practical significance was given to the experiments by applying all dusts with tractor-mounted dusters. In timing the applications due consideration was given those risks facing the grower.

The 1947 season was very favorable for boll weevil development. Early spring temperatures were about normal and precipitation was slightly above normal. There was no precipitation during the first 20 days of May but from that time until harvest there was an excess from the standpoint of cotton production. There was rain on 8 days in June, totaling 5.90 inches, on 8 days in july, totaling 3.10 inches, and on 13 days in August, totaling 10.09 inches. When the dry period during the early part of May was broken, weevils began coming out of hibernation in appreciable numbers and by the first week in June they were in cotton fields in abundance. By the second week in June, when squares were large enough to be attacked by the weevil, square infestations ran generally from 15 per cent to 30 per cent.

PLOTS AND TREATMENTS.—In the plot experiment five treatments and a check

[1] Technical contribution No. 153 South Carolina Agricultural Experiment Station in cooperation with the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture.

[2] Cotton States Branch program paper.

[3] Entomologist, South Carolina Agricultural Experiment Station.

[4] Veran K. Quattlebaum Agent, Bureau of Entomology and Plant Quarantine, U.S.D.A., assisted in the work reported in this paper.

were replicated six times. Because of the size of the plots, approximately 0.5 acre each, a single field was not available which would satisfactorily accommodate all six replications; consequently, in order to obtain greater soil uniformity, the experiment was set up with two replications in each of three adjoining fields. The plots were rectangular in shape, approximately 100 by 200 ft., either an acre long and a half acre wide or a half acre long and an acre wide.

In the large scale field comparisons four dust formulations and a check were used.

All dusts were applied with an eight-row, tractor mounted duster at the rate of approximately 8 pounds per acre in the plots as well as in the individual fields. The machines delivered this quantity of dust quite uniformly and excellent coverage was obtained.

A proprietary spray mixture was diluted in accordance with the manufacturers' recommendation and applied with a two-row, horse drawn traction sprayer at the rate of about 1.25 gallons of the concentrate per acre.

No fixed schedule of application was followed, but rather a more "practical" one which, in addition to the percentage of infested squares, gave due consideration to the financial investment, weather conditions, and the accompanying risk of rain within 24 hours after treatment.

RECORDS.—The boll weevil infestation records were begun the week ending June 14, the week preceding the first application of insecticides, and were continued through the week ending August 2, giving a total of eight consecutive weekly records. The sampling technique consisted of examination of three 100-square samples from among the 10 center rows of each plot and from about equally spaced points with respect to their length. At the point selected for sampling, squares were examined on consecutive plants until the sample was completed. In the various fields receiving the different treatments, from 1 to 12, 100-square samples were taken depending on the size of the field.

Five cotton aphid records were taken on the replicated plots during the weeks ending June 28, July 5, 19, August 2, and 9. The samples consisted of counting the number of aphids on one square inch of lower leaf surface at the base of the fourth leaf from the top of 100 consecutive plants near the center of the plots. Aphid records were not taken from the various fields.

The yield records represent the total seed cotton picked from the entire plot or field, as the case may be, and are converted to pounds per acre.

EXPERIMENT 1.—The objective of this experiment was to compare three chlorinated hydrocarbon dusts with the standard calcium arsenate/nicotine dust in controlling cotton insects, and to establish the relative effectiveness of a proprietary spray mixture which was being widely publicized and distributed for cotton insect control.

The treatments consisted of commercial grades of the following: (1) A mixture containing 5 per cent DDT, and 3 per cent gamma benzene hexachloride. (2) 4.8 per cent gamma isomer. (3) 20 per cent chlorinated champhene.[1] (4) Calcium arsenate containing 1 per cent nicotine derived from a 14 per cent nicotine dry concentrate. (5) A proprietary boll weevil spray.[2] This is a liquid concentrate which directions state should be diluted one part to 11.5 parts of water. The manufacturer advertises that it should be used at the rate of one gallon of concentrate per acre per application for at least four applications, beginning when the cotton is in the three leaf stage. According to the Manufacturers' label it contains the following:

Copper, present as basic sulphate, as metallic	1.50%
Zinc, present as basic sulphate, as metallic	1.25%
Lead Arsenate, as $PbHAsO_4$	0.50%
Calcium Arsenate, as $Ca_3(AsO_4)_2$	0.40%
Pyrethrins	0.13%
Mineral Oil	21.00%
Inert ingredients	75.22%
Total	100.00%

Total arsenic, as metallic, not less than 0.26%; water soluble arsenic, as metallic, not more than 0.10%; lead as metallic, not less than 0.33%.

(6) Check—no treatment.

Applications were started on June 20, at which time square infestations averaged about 36 per cent. Five applications of poison were made between this date and August 7. Harvest began about August 20.

RESULTS.—BOLL WEEVIL.—The DDT-benzene hexachloride mixture and the 4.8

[1] Supplied by Hercules Powder Co.
[2] Supplied by A. C. Matthews Co., Columbia, S. C.

Table 1.—Boll weevil and cotton aphid infestations and yield of cotton on six blocks of plots receiving various insecticidal treatments. Edisto Experiment Station, Blackville, S. C., 1947.

TREATMENT[1]	BOLL WEEVIL PUNCTURED SQUARES	APHIDS PER 100 SQUARE INCH	POUNDS OF SEED COTTON PER ACRE	INCREASE OVER CHECK	
				Pounds	Per Cent
Check	47.17%	54.9	570.2		
DDT 5%/Benzene Hexachloride 3% gamma	30.78	19.9	1014.5	444.3	77.9
DDT 5%/BHC 3% gamma	30.78	19.9	1014.5	444.3	77.9
BHC 4.8% gamma	30.72	23.6	913.1	342.9	60.1
Chlorinated Camphene 20%	36.88	39.6	830.8	260.6	45.7
Calcium Arsenate & 1% Nicotine	38.61	67.9	781.3	211.1	37.0
A Proprietary Boll Weevil Spray	45.81	48.6	634.3	64.1	11.2
Least Significant Difference:					
5% level	4.14	9.99	122.98		
1% level	5.60	13.52	166.38		

[1] Dusted: June 20, 28,* July 11, 23, August 7,† at about 8 lbs. per acre.
* 0.20 inches rain after 12 hours.
† 0.22 inches rain after 12 hours.

per cent gamma isomer gave equal protection against the boll weevil (Table 1). The 20 per cent chlorinated camphene and calcium arsenate/1 per cent nicotine were approximately equal in protecting squares but they were each significantly less effective than the two dusts containing gamma isomer. All dust treatments were superior to the proprietory spray mixture whose average infestation was not measurably different from the untreated check.

APHIDS.—The cotton aphid population was light and probably did not affect yields, nevertheless a significant difference in population density was observed between plots receiving different treatments (Table 1). The DDT-benzene hexachloride mixture and the 4.8 per cent gamma isomer were about equally effective against aphids, and both were superior to chlorinated camphene. The aphid population was about equal on the proprietary spray mixture and untreated check plots. There was a significant increase in aphids on the calcium arsenate-nicotine plots over the untreated check.

BOLL WORM.—No records were taken on boll worm injury but it was generally unimportant except in plots treated with 4.8 per cent gamma isomer where it caused limited damage.

RED SPIDER.—Red spiders were of no importance in the plots or on surrounding dusted or undusted cotton. One light infestation covering a few hundred plants developed late in the season.

YIELDS.—The DDT-benzene hexachloride mixture produced yields significantly greater than all other treatments except 4.8 per cent gamma isomer. The yields of this latter treatment were significantly better than calcium arsenate nicotine, but were not significantly better than the chlorinated camphene. All dust treatments produced yields significantly greater than the proprietary spray mixture, which was not significantly better than the untreated check.

GINNING PERCENTAGE.—The ginning percentage was determined on samples of seed cotton from all replications of each treatment but there was no significant difference.

EXPERIMENT 2.—The object of this experiment was to make a large-scale comparison of the four dust preparations used in Experiment 1. Each dust was applied to two or more fields under conditions which would normally be employed by a grower. The cotton was all of one variety, *Coker-100*, and the fertilization and culture were essentially the same in all fields. On the other hand there were variations in soil

Table 2.—Results of large-scale comparisons of different insecticides against the boll weevil.* Edisto Experiment Station, Blackville, S. C., 1947.

Treatment and Field No.	No. of Applic.	Area in Acres	Yield of Seed Cotton			Increase Over Check		Average Per Cent Punctured Squares
			total lbs.	Pounds	per acre	Pounds	Per Cent	
Check								
6B	0	1.6	362	226				
17	0	2.7	522	193				
Totals		4.3	884	206†				49.8
DDT 5%, Benzene hexachloride 3% gamma								
2	5	14.6	17,195	1178				
9A	5	6.1	5,086	834				
11	4	26.5	22,880	863				
12	4	31.5	29,011	921				
13	3	5.3	6,259	1183				
16	4	2.7	881	326				
18	4	4.7	3,702	788				
19	3	4.1	4,606	1123				
Totals		95.5	89,630	939†		733	356	28.3
Benzene hexachloride 20%								
6A	5	7.4	6,295	851				
7	5	2.3	1,455	633				
10B	3	24.4	21,826	895				
Totals		34.1	29,576	867†		661	321	24.7
Chlorinated camphene 20%								
3	5	6.5	5,146	792				
4	5	15.3	10,007	654				
5	5	16.6	11,684	704				
9B	3	18.0	11,975	665				
Totals		56.4	38,812	688†		482	234	32.5
Calcium Arsenate with 1% Nicotine								
1	5	3.7	1,743	471				
8	5	3.4	4,156	1222				
10A	3	11.8	6,196	525				
Totals		18.9	12,095	640†		434	211	39.0

* All treatments were at the rate of about 8 pounds per acre per application.
† Weighted average.

productivity, number of applications of dust, source and degree of infestation, and some variation in planting date. Therefore, the only justified comparison is between the average yields from the various treatments. The boll weevil was the only insect of importance in any of the fields except in those treated with 4.8 per cent gamma isomer where there was somewhat more boll worm damage than elsewhere.

The results of this experiment are given in table 2. The order of performance of the four dust preparations was the same here as in the replicated plot experiment; however, it is felt that the very low yields from the untreated check fields do not represent a true basis for evaluating the benefits of the insecticides. It is believed that local variables such as those already mentioned were partly responsible for the very low yields in the untreated fields. It is quite unlikely that increases over the check as great as those obtained would have resulted had all conditions been uniform except insect control.

Soil Toxicity from Chlorinated Hydrocarbons.—Because of the potential widespread use of chlorinated hydrocarbons on cotton and other crops it is important to know the extent to which

Table 3.—Response of various crops to differ-rates of three chlorinated hydrocarbon insecticides on Grady sandy loam soil. Edisto Experiment Station, Blackville, S. C., 1947.[1]

	6% GAMMA BENZENEHEXACHLORIDE		
	Pounds per acre		
	200	400	2000
Cantaloupe	−	++	+++
Cucumber	−	++	+++
Watermelon	−	++	+++
Squash	−	++	+++
Cabbage	−	+++	++++
Raddish	−	+++	++++
Turnip	−	+++	++++
Carrot	−	++	+++
Beet	−	+++	++++
Henderson Lima	−	−	++
Calico Lima Bean	−	−	++
Logan Snap Bean	−	++	++++
Cowpea	−	−	++
Peanuts	−	+++	++++
Sweet Corn	−	+++	++++
Hybrid sweet corn	−	+++	++++
Grain sorghum	+++	+++	++++
Okra	−	+++	++++
Cotton	−	+	++

[1] No injury was shown to result from the application of either DDT or chlorinated camphene at any of these rates or from benzene hexachloride at rates below 100 pounds per acre.

they may accumulate in the soil and become toxic to growing plants. Two types of soil were selected, a heavy one-Grady sandy loam, and a light one—Norfolk sandy loam deep phase, on which to make exploratory observations. Nineteen crops were seeded to soil which had been treated the same day with five different rates of 50 per cent DDT, 6 per cent gamma isomer and 36 per cent chlorinated camphene. The insecticides were applied by hand in the drill, approximately an inch below the seed. The resulting effect on plants growing on Grady sandy loam is shown in table 3.

There was no apparent injury to any of the crops by any rate of DDT or chlorinated camphene. However, all crops showed from light to severe reduction in stand at 2000 lbs. per acre of 6 per cent gamma isomer and all except cowpeas, calico lima beans and Henderson lima beans showed very light to moderate reduction in stand at 400 lbs. per acre. At 200 lbs. per acre only grain sorghum showed a reduction in stand. No injury was apparent on any of the crops at 40 or 100 lbs. per acre. In most cases where a reduction in stand occurred the seedlings came up to a fairly even stand and after a few days many of them wilted and died. It is significant that even at the higher rates some of the plants survived and appeared to mature in a normal manner.

An irregular stand of most crops on the Norfolk sandy loam deep phase made accurate comparisons impossible. However, no injury was apparent to any crop at any rate of DDT or chlorinated camphene, but injury from benzene hexachloride was relatively more severe than on the heavier Grady sandy loam.

SUMMARY.—In replicated plots and large-scale field tests a dust mixture containing 5 per cent DDT and 3 per cent gamma isomer was the most effective of five insecticide formulations in increasing cotton yields. A 4.8 per cent gamma isomer dust gave equal boll weevil control although yields were slightly, though not significantly, less. A 20 per cent chlorinated camphene ranked third in increasing cotton yields but it was not significantly better than calcium arsenate containing 1 per cent nicotine. A proprietary boll weevil spray which has been widely publicized and distributed failed to increase cotton yields over the untreated check significantly.

In preliminary tests on Grady sandy loam, a moderately heavy soil, 50 per cent DDT and 36 per cent chlorinated camphene applied to the soil at rates as high as 2000 lbs. per acre at the time of seeding caused no apparent injurious effects to any of nineteen crops. Similarly applied, 6 per cent gamma isomer at 2000 lbs. per acre caused light to severe reduction in stand of all crops. At 100 lbs. per acre none of the crops showed any apparent injury. It is significant that at all rates some of the plants survived and appeared to mature in a normal manner.—2-14-48.

Tests of Insecticides for the Control of Several Cotton Insects[1]

J. C. GAINES and H. A. DEAN, *Texas Agricultural Experiment Station, College Station*

The efficacy of some of the new insecticides in controlling cotton insects has been reported in recent issues of the JOURNAL. At the Texas Station, investigations have been continued in an effort to evaluate these materials for the control of the cotton fleahopper, *Psallus seriatus* Reut., boll weevil, *Anthonomus grandis* Boh., bollworm, *Heliothis armigera* (Hbn.) and cotton aphid, *Aphis gossypii* Glov. For some time it has been realized that one insecticide or insecticidal mixture, effective against all cotton insects, is needed by planters aiming at maximum profits from an insect control program. These new insecticides offer such a possibility.

The field tests herein reported, conducted in the Brazos river bottoms near College Station, Texas, during 1947, were designed to compare new insecticides with the old materials which have been recommended for economical control of cotton pests. Several plat-arrangements, each designed for specific comparisons, were used. The plat-size varied in the experiments from one-tenth of an acre to 5 acres. Dust applications were made in the early morning with rotary hand guns, with the exception that a power duster was used on the large plats. Infestation records were made in the usual manner at 5-day intervals. The seasonal averages for the various criteria are shown in tabular form. Abbott's formula was used to calculate the percentage controls.

The percentages of boll weevil infestation and bollworm injury were transformed to equivalent angles for analysis. One of the essential features of the analysis of variance is that the pooled error gives a single estimate upon which the variation due to treatment can be compared. However, when the experimental results are in terms of percentages, the error is a function. Bliss (1938) has shown that the most convenient way to eliminate this variability would be to transform the observed percentages to equivalent angles.

COTTON FLEAHOPPER.—In certain years the cotton fleahopper causes considerable injury early in the season, particularly in South Texas. Sulphur dust has been used to control this pest. In most cases several applications are required to prevent injury even when the population is low. This material has little effect on the adult hoppers, but a mixture containing 5 per cent DDT has proved to be highly effective against both adults and nymphs.

In normal years, fleahoppers migrate to cotton from weed host plants early in the season. Later, usually by the first week in July, this pest disperses out of cotton. The past year proved to be no exception, since large numbers of adult hoppers migrated into cotton fields during the first part of June. This condition made it necessary to apply insecticides for the control of these adults.

Experiment 1, as shown in table 1, was conducted to determine the effectiveness of the following 6 materials when used against fleahoppers: (1) 1 per cent parathion[2]-inert, (2) 1 per cent gamma benzene hexachloride-sulphur, (3) 5 per cent DDT-sulphur, (4) 5 per cent chlordane-inert, (5) 5 per cent chlorinated camphene-sulphur, and (6) sulphur. The plats were arranged in randomized blocks, each plat being 18 rows wide and of sufficient length to make one-fourth acre. The blocks were duplicated and contained untreated plats. Only one application of the materials was made (June 26) using the average rate of 12 pounds per acre. No other insecticidal treatments were necessary during the remainder of the season.

These data indicate that all the organic insecticides used, even at low concentrations, were effective against the fleahopper. Economical gains in yield were realized from all the materials with the exception of sulphur.

Experiment 2, as shown in table 2, designed for the same purpose as the preceding test was carried on in another location. The following materials were used against the fleahopper: 1 per cent gamma

[1] Technical contribution No. 1091 Texas Agricultural Experiment Station in cooperation with the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture. Thanks are due R. Wipprecht, R. L. Hanna, Wm. McGee, R. L. Houk, R. S. Hogue, G. L. Atmar and J. F. Gibson, for assistance in taking the field note.

[2] o,o-diethyl o-p-nitrophenyl thiophosphate.

Table 1.—The initial fleahopper population, per cent control and yield on experiment 1, College Station, Tex.

TREATMENT	INITIAL POPULATION[1]	PER CENT CONTROL AFTER DUST APPLICATION						YIELD, GAIN OVER CHECK[2]
		1 day	2 days	3 days	4 days	5 days	Average	
Parathion-inert (1% parathion)	48.0	95.4	84.6	85.0	77.4		85.6	205
Benzene hexachloride-sulphur (1% gamma isomer)	36.2	96.0	96.4	83.4	62.8	82.3	84.3	111
DDT-sulphur (5% DDT)	27.0	60.0	80.7	78.2	81.6		75.1	147
Chlordane-inert (5% chlordane)	50.5	91.2	81.1	85.8	75.5		83.4	140
Chlorinated camphene—sulphur (5% chlorinated camphene)	37.5	82.9	83.2	80.2	57.6	69.2	74.6	138
Sulphur	35.2	.0	19.2	53.8	44.4	48.3	33.1	62

[1] Adults and nymphs per 100 terminals.
[2] Per acre.

benzene hexachloride, 5 per cent DDT-sulphur, 5 per cent chlorinated camphene-sulphur and sulphur. The plats, each 12 rows wide and of sufficient length to make one-tenth of an acre, were arranged in randomized blocks. Each block was replicated three times and included untreated plats.

The organic insecticidal mixtures were more effective against the fleahopper than was sulphur. The materials did not remain effective as long as 7 days against large numbers of adult hoppers migrating into the plats. The second application of dusts was necessary on the eighth day following the first application to prevent serious injury. Apparently the residual action of these materials was limited, and therefore, could not be relied upon to protect cotton over an extended period.

Experiment 3, as shown in table 3, was located in a different field and included the same materials as were used in the preceding test. The plats, each 12 rows wide and of sufficient length to make one-tenth of an acre, were arranged in randomized blocks. Each block was replicated 4 times and included untreated plats.

The results were similar to those obtained in experiment 2. The 1 per cent gamma benzene hexachloride-sulphur, 5 per cent DDT-sulphur and 5 per cent chlorinated camphene-sulphur were more

Table 2.—The initial fleahopper population and per cent control on experiment 2, College Station, Tex.

TREATMENT	INITIAL POPULATION[1]	PER CENT CONTROL AFTER DUST APPLICATIONS					
		First Application			Second Application		AVERAGE
		2 days	4 days	7 days	1 day	2 days	
Benzene hexachloride-sulphur (1% gamma isomer)	44.3	95.8	44.7	12.3	97.3	59.0	61.8
DDT-sulphur (5% DDT)	61.0	90.8	33.0	24.6	69.6	70.2	57.7
Chlorinated camphene-sulphur (5% chlorinated camphene)	65.3	79.9	30.4	37.5	84.9	97.2	66.0
Sulphur	44.7	0.0	0.0	13.1	0.0	26.8	8.0

[1] Adults and nymphs per 100 terminals.
First application was made 6/24, second on 7/2 at the average rate of 12 pounds per acre.

Table 3.—The initial fleahopper population and per cent control on experiment 3, College Station Tex.

Treatments	Initial Population[1]	Per Cent Control After Dust Applications					
		First Application		Second Application			Average
		4 days	10 days	1 day	3 days	6 days	
Benzene hexachloride-sulphur (1% gamma isomer)	23.0	63.4	0.0	95.7	92.2	72.2	64.7
DDT-sulphur (5% DDT)	28.5	54.7	0.0	81.4	95.1	86.0	63.4
Chlorinated camphene-sulphur (5% chlorinated camphene)	34.0	54.0	5.8	90.4	89.1	79.3	78.2
Sulphur	23.5	1.7	0.0	27.1	45.1	12.4	21.6

[1] Adults and nymphs per 100 terminals.
First application was made 6/14, second on 6/25 at the average rate of 13.5 pounds per acre.

effective against fleahoppers than sulphur alone. Practically no control was obtained from any of the dust mixtures on the tenth day after the first application was made. This indicates that the materials did not remain effective as long as 10 days against large numbers of adults migrating into the plats from weed host plants. The residual effect was again limited and could not be relied upon to protect cotton over an extended period. The second application was effective in reducing the population.

COTTON FLEAHOPPER, BOLL WEEVIL AND BOLLWORM.—The objective of experiment 4 was to obtain information on the value of insecticides, both as contact and stomach poisons in a schedule of applications, for control of all cotton insects. This factorial-type experiment afforded valid comparisons between several treatments, *i.e.*, no treatment, 5 per cent DDT-sulphur mixture alone, 3 stomach poisons and the combination of the DDT-sulphur mixture with later applications of the stomach poisons. In this experiment, all plats were utilized in making estimates of the effects of the different treatments, thus giving greater precision than could be obtained from separate experiments.

The experiment consisted of 36 plats, each plat 12 rows wide and of sufficient length to make one-tenth of one acre (dusting area). The picking area, after buffers were eliminated, was one twenty-fifth of an acre. The plats were arranged in blocks, each block contained 12 plats. In each block, 6 plats selected at random were treated with 5 per cent DDT-sulphur for fleahopper control, 3 of which were later treated with stomach poisons. One plat received each of the following: calcium arsenate, 3 per cent gamma benzene hexachloride-5 per cent DDT-sulphur and 20 per cent chlorinated camphene-sulphur. Of the remaining 6 plats, 3 were treated with a different stomach poison as above and 3 were left untreated.

Three applications of 5 per cent DDT-sulphur were made at the average rate of 13 pounds per acre for fleahopper control from June 10 to 25. Eight effective applications of the stomach poisons were made at the average rate of 11 pounds per acre for weevil and bollworm control from July 1 to August 6.

Analyses of variance using the seasonal plat averages of fleahopper population, boll weevil infestation, bollworm injury and yield of seed cotton, are shown in tables 4 and 5. The averages for these different criteria were computed by using the number of plats as shown in table 6. As indicated by comparisons of various combinations, information was obtained

Table 4.—Analysis of variance with respect to fleahopper population in experiment 4, at College Station, Tex.

Source of Variation	DF	Sum of Squares	Mean Square
Blocks	2	284.96	142.48
Treatments	1	1604.00	1604.00*
Error	32	1150.41	35.95
Total	35	3039.37	86.84

* Highly significant.

Table 5.—Analysis of variance with respect to boll weevil infestation, bollworm injury, aphid population and yield on experiment 4 at College Station, Tex.

Source of Variation	DF	Mean Square Pertaining to: Boll Weevil Infestation, Angles	Bollworm Injured Bolls, Angles	Aphid Population, Number	Yield Per Plat, Pounds
Blocks	2	149.71†	91.45†	65.29	43.82
Level of contact insecticide	1	57.68*	7.95	5.00	76.85
Level of stomach poisons	1	2994.10†	947.41*	.35	2826.69†
Source of stomach poisons	2	38.99	38.64†	523.87†	231.26†
Contact×stomach poisons	1	45.36*	4.91	19.33	1.0
Contact×source of stomach poison	2	4.73	1.81	13.44	12.15
Error	26	13.16	8.89	63.85	38.44
Total	35	109.32	41.58	82.57	127.96

* Significant.
† Highly Significant.

on the responses to the different insecticides and to each contact and stomach poison. Data were also secured on the effect of applications of DDT-sulphur alone and followed by applications of each of stomach 3 poisons.

The yield is the most important criterion for estimating the control of all insects in this experiment. It was possible for the early applications of DDT-sulphur to affect the fleahopper population and fruit production, but it was not possible for the later applications of stomach poisons to affect the fleahopper population. Hence, as far as the fleahopper population was concerned, the experiment was a simple one and the data were analyzed as shown in table 4.

The stomach poisons affected all the insects with the exception of the fleahoppers which were present before the posions were applied. Comparisons of the effect of stomach poisons, with and without earlier fleahopper control are valid and important. These data are analyzed in table 5 and the means for the various

Table 6.—The average fleahopper infestation, boll weevil infestation, bollworm injury, aphid population and yield of seed cotton on experiment 4 at College Station, Tex.

Treatments	Average Flea Hopper Population[1] Number	Average Boll Weevil Infestion[2] Per Cent	Average Bollworm Injured Bolls[3] Per Cent	Average Aphid Population[4] Number	Average Yield: Per Plat	Average Yield: Acre
No-DDT-Sulphur (18 plats)	24.8	34.6	9.6	8.47	49.55	1239
DDT-Sulphur (18 plats)	11.5	38.9	10.8	7.73	52.47	1312
No stomach poison (18 plats)	18.9	51.6	15.3	8.20	42.15	1054
Stomach poisons (18 plats)	17.4	21.8	5.1	8.00	59.87	1497
No treatment (9 plats)	25.0	47.5	14.3	7.84	40.86	1022
DDT-Sulphur alone (9 plats)	12.8	55.7	16.3	8.56	53.44	1086
Stomach poisons alone (9 plats)	24.7	21.6	4.9	9.11	58.24	1456
DDT-sulphur plus stomach poisons (9 plats)	10.2	22.1	5.3	6.90	61.50	1538
Calcium arsenate (6 plats)	19.0	17.2	7.0	23.13	50.75	1269
Calcium arsenate alone (3 plats)	28.9	16.7	6.9	26.74	51.40	1285
Calcium arsenate plus DDT-sulphur (3 plats)	9.1	17.6	7.2	19.52	50.10	1252
Benzene hexachloride-DDT-sulphur (6 plats)	17.4	25.7	3.0	.25	65.78	1643
Benzene hexachloride-DDT-sulphur alone (3 plats)	24.1	24.0	3.2	.19	62.90	1572
Benzene hexachloride-DDT-sulphur plus DDT-sulphur (3 plats)	10.8	27.4	2.7	.30	68.57	1714
Chlorinated camphene-sulphur (6 plats)	15.9	22.6	5.2	.63	63.13	1578
Chlorinated camphene-sulphur alone (3 plats)	21.2	24.0	4.5	.39	60.43	1511
Chlorinated camphene-sulphur plus DDT-sulphur (3 plats)	10.7	21.2	5.9	.87	65.83	1646

In all cases the DDT-sulphur was applied early in the season for flea hopper control.
[1] Average of 4 records made from June 14 to June 30.
[2] Average of 5 records made from July 4 to July 22.
[3] Average of 4 records made from July 28 to Aug. 11.
[4] Average of 3 records made from July 24 to Aug. 5.

comparisons are shown in table 6.

Applications of DDT-sulphur were effective in reducing the fleahopper population, however, this difference in fleahopper population did not significantly affect the yield. Apparently the population was not sufficiently high to cause reductions in yields.

The applications of stomach poisons significantly reduced the percentage of boll weevil infestation and bollworm injury and significantly increased the yield. Benzene hexachloride-DDT-sulphur and chlorinated camphene-sulphur gave significantly better control of the bollworm and better yield than did calcium arsenate. The 3 stomach poisons were equally effective against the weevils. The aphid population increased to injurious numbers on the plats treated with calcium arsenate. The two organic insecticidal mixtures did not produce increased aphid infestations.

Experiment 5, as shown in table 7, was to demonstrate the effectiveness of 3 per cent gamma benzene hexachloride-5 per cent DDT-sulphur, 20 per cent chlorinated camphene-sulphur and calcium arsenate-sulphur followed by calcium arsenate for the control of all cotton insects. Five-acre plats each 48 rows wide were used. The dust applications were made with an 8-row tractor machine. Five effective applications were made on June 17, July 10, 16, 25 and August 6 at the average rate of 10 pounds per acre.

The application on June 17 was effective in reducing the fleahopper population on all plats. The calcium arsenate was more effective against weevils than either of the organic insecticides, but the organics were more effective against bollworm. The yield was highest on the plat treated with benzene hexachloride-DDT-sulphur mixture. This mixture gave better control of the weevil than chlorinated camphene and better control of the bollworm than did calcium arsenate, thus resulting in a high yield.

In another experiment, the details of which are not given in this paper, 2 applications of 5 per cent chlorinated camphene were necessary to control the fleahopper infestation. The 10 per cent chlorinated camphene-sulphur was effective in reducing the weevil infestation early in the season. However, the 10 per cent mixture was not as effective against bollworms as the 20 per cent mixture. The plat dusted with 20 per cent chlorinated camphene-sulphur produced 245 pounds or 18 per cent more seed cotton per acre, than the plat treated with 10 per cent chlorinated camphene-sulphur.

Table 7.—The average fleahopper population, boll weevil infestation, bollworm injury and yield of seed cotton on experiment 5 at College Station, Tex.

Treatments	Average Flea Hopper Population[2] Number	Average Boll Weevil Infestation[3] Per Cent	Average Bollworm Inj. Bolls[4] Per Cent	Average Yield Seed Cotton Per Acre Pounds
Calcium arsenate[1]	15.7	7.3	12.2	1342
Benzene hexachloride-DDT-Sulphur (3% gamma isomer, 5% DDT)	9.2	22.6	6.7	1575
Chlorinated camphene-sulphur (20% chlorinated camphene)	6.4	34.3	2.2	1368

[1] Calcium arsenate–sulphur (1–2) was used for flea hopper control.
[2] Average of 4 records from June 17 to July 5.
[3] Average of 5 records from July 9 to July 28.
[4] Average of 3 records from July 24 to July 31.

BOLLWORM.—Experiment 6, as shown in table 8, was to determine the effectiveness of the following materials against the bollworm: 2 per cent parathion-inert, 20 per cent chlordane-inert, 20 per cent chlorinated camphene-sulphur, 3 per cent gamma benzene hexachloride-5 per cent DDT-sulphur and calcium arsenate. The plats were arranged in randomized blocks. Each plat was 19 rows wide and of sufficient length to make one-sixth of one acre. Each treatment was replicated 4 times. Five applications of the materials were made at 5-day intervals from July 16 to August 8, at an average rate of 12 pounds

Table 8.—The boll weevil infestation, bollworm injury and yield of seed cotton on experiment 6 at College Station, Tex.

TREATMENTS	AVERAGE WEEVIL INFESTATION PER CENT	AVERAGE BOLLWORM INJURED BOLLS[1] PER CENT	ANGLES[1]	SEED COTTON Per Plat Pounds	Per Acre Pounds	Gain Over Check Pounds
Check	8.7	13.2	21.0	111.85	1118	
Parathion-inert (2% parathion)	3.2	14.0	21.5	98.40	984	−134
Calcium arsenate	6.3	4.2	11.7	161.38	1614	496
Chlordane-inert (20% chlordane)	4.9	6.6	14.6	152.0	1520	402
Chlorinated Camphene-sulphur (20% chlorinated camphene)	3.4	2.3	8.5	159.02	1590	472
Benzene hexachloride-DDT-sulphur (3% gamma isomer 5% DDT)	5.4	1.4	6.9	161.85	1618	500
Minimum significant difference at 5% level			5.2	42.5		

[1] Average of 4 records made July 29 to Aug. 13.

per acre. Analyses of variance were made using the seasonal plat averages for bollworm injury and yields.

The low weevil infestation did not affect the yields on any of the plats. One brood of bollworms caused considerable injury on the unprotected plats. Aphid populations did not increase as a result of any of the insecticidal treatments.

The chlorinated camphene and the benzene hexachloride-DDT mixture gave significantly better control of the bollworm than did chlordane. Parathion was ineffective against this pest. Using yields as the criterion, all the insecticides except parathion produced significant gains over the untreated plats.

APHIDS.—Experiment 7, as shown in

Table 9.—Cotton aphid control on experiment 7 at College Station, Tex.

TREATMENTS	INITIAL INFESTATION[3]	PER CENT AFTER DUST APPLICATION 8 hours	32 hours	56 hours	80 hours	104 hours	Average
Parathion-inert (2% parathion)	46.5	94.4	100.0	100.0	100.0	100.0	98.9
Chlorinated camphene-benzene hexachloride-sulphur[1]	35.0	81.6	93.1	94.4	94.8	94.9	91.8
Benzene hexachloride-sulphur (3% gamma isomer)	33.6	77.9	91.8	89.1	87.8	90.0	87.3
Benzene hexachloride-sulphur (3% gamma isomer)	39.7	76.4	87.0	88.0	83.4	84.1	83.8
Benzene hexachloride-DDT-Sulphur[2]	29.6	80.8	92.2	91.0	93.9	89.4	89.5
Chlorinated camphene-sulphur (15% chlorinated camphene plus oil)	33.2	11.2	48.7	47.5	33.5	38.3	35.8
Chlorinated camphene-sulphur (15% chlorinated camphene)	37.4	11.3	25.5	25.9	17.3	13.4	18.7
Sulphur	44.0	26.1	34.1	31.3	27.1	25.3	28.3

[1] 15% chlorinated camphene, 2% gamma isomer.
[2] 3% gamma isomer, 5% DDT.
[3] Number aphids per square inch.

table 9, was to determine the effectiveness of the following materials as a "knock-out" control of aphids: 2 per cent parathion-inert, 2 per cent gamma benzene hexachloride-15 per cent chlorinated camphene-sulphur, 3 per cent gamma benzene hexachloride-sulphur, 2 per cent gamma benzene hexachloride-sulphur, 3 per cent gamma benzene hexachloride-5 per cent DDT-sulphur, 15 per cent chlorinated camphene-sulphur plus oil, 15 per cent chlorinated camphene-sulphur and sulphur. The plats were arranged in duplicated randomized blocks. Each plat was 4 rows wide and 130 feet long, separated by an equal number of untreated rows, in order to eliminate the possibility of drift from one plat to another.

The number of aphids was recorded on 40 leaves in each plat. Tags were placed on the leaves in order that the same leaves might be examined on each date to eliminate as much variation as possible. One-half of the tagged leaves were near the tops of the plants and the remaining half were near the bases of the plants. Only 2 leaves were tagged per plant. This method provided accurate readings of the aphid populations. Only one application of the insecticides was made on August 19 at the average rate of 12 pounds per acre.

Parathion proved to give excellent control of aphids. Benzene hexachloride dust containing as low as 2 per cent gamma isomer alone or in combination with DDT or chlorinated camphene also gave good control of aphids. The chlorinated camphene-sulphur or sulphur gave poor control and could not be relied upon to combat heavy populations of aphids.

SUMMARY.—The results of 3 experiments indicate that the following mixtures were effective against fleahoppers: 1 per cent parathion-inert, 1 per cent gamma benzene hexachloride-sulphur, 5 per cent chlordane-inert, 5 per cent DDT-sulphur and 5 per cent chlorinated camphene-sulphur. Sulphur alone was not as effective as the sulphur-organic insecticide mixtures. Only one application of these materials gave an economical increase in yield.

Applications of 5 per cent DDT-sulphur used in a factorial experiment decreased the fleahopper population, however, this low population did not affect the yields. Twenty per cent chlorinated camphene-sulphur and 3 per cent gamma benzene hexachloride-5 per cent DDT-sulphur gave significantly better control of the bollworm and higher yields than calcium arsenate. All 3 poisons were equally effective against the boll weevil. Of the 3, only calcium arsenate produced increased aphid populations.

In a demonstration using 5-acre plats, the 3 per cent gamma benzene hexachloride-5 per cent DDT-sulphur gave better control of the bollworm than did calcium arsenate, but no better control of the weevil. This mixture gave better control of the boll weevil than 20 per cent chlorinated camphene-sulphur. The highest yield was produced on the plat treated with benzene hexachloride-DDT-sulphur mixture.

The 20 per cent chlorinated camphene-sulphur mixture proved to be more effective against bollworms than the 10 per cent mixture.

In the randomized block experiment, where the bollworm was the primary pest, 20 per cent chlorinated camphene-sulphur and 3 per cent gamma benzene hexachloride-5 per cent DDT-sulphur gave significantly better control than did the 20 per cent chlordane-inert dust. The chlordane mixture and calcium arsenate were equally effective, but the yields did not differ significantly between the organics and calcium arsenate.

The 20 per cent chlorinated camphene-sulphur and 3 per cent gamma benzene hexachloride-5 per cent DDT-sulphur were more effective against the bollworm than calcium arsenate. Calcium arsenate was as effective as these organic sulphur mixtures when used against the boll weevil. In 2 experiments, these two organic sulphur mixtures produced more cotton than did calcium arsenate, while in another the calcium arsenate produced as much as the organics. Aphid increases did not result from the use of the organic sulphur mixtures.

Parathion and benzene hexachloride were effective in reducing heavy populations of cotton aphids.—4-20-48

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Control of Sucking Bugs That Cause Deformed Peaches

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Experiments conducted in 1944 and 1945 (Snapp 1946) showed that good control of sucking bugs that cause deformed peaches can be expected from spraying or dusting with DDT, and experiments conducted in 1946 (Snapp 1947) showed that benzene hexachloride had promise for the control of these insects. This paper, which is the third report on experiments for control of sucking bugs on peaches, gives the results from DDT and benzene hexachloride sprays on different schedules, of tests of the fog machine for applying DDT to peach orchards for sucking bug control, and of further observations on the insects that may be responsible for the deforming of peaches in South Carolina.

ORCHARD EXPERIMENTS.—Large-scale orchard experiments were conducted during 1947 in a six-year-old Halehaven peach orchard at Cross Anchor, South Carolina, which produced a very high percentage (about 40 per cent) of peaches injured by sucking bugs in 1946. Jarring untreated trees in this orchard early in the morning on April 12, when about 85 per cent of the petals had fallen, and on April 25, when 50 to 75 per cent of the shucks had shed, showed the presence of both tarnished plant bugs and pentatomids.

There were 8 unreplicated plots averaging about 275 trees each. One pound of DDT, mixed and micronized with an equal weight of pyrophyllite, and 1 pint of fish-glue solution (1 pound per gallon of water) was used with each 100 gallons of spray. The benzene hexachloride was a 31.6 per cent (technical grade) wettable powder containing 3.79 per cent of the gamma isomer, used at the rate of 1 pound per 100 gallons. The curculio spray was a mixture of lead arsenate, basic zinc sulfate and sulfur used at the rate of 16 pounds per 100 gallons of spray to which was added 8 pounds of hydrated line per 100 gallons of spray. All sprays were applied with a 400-gallon sprayer, with power take-off from a tractor. Four-nozzle brooms were used on spray rods for applying the sprays at 500 pounds' pressure.

After the adequacy of the sampling procedure had been determined, 50 peaches on each of 10 record trees scattered throughout each plot were examined June 23 to 26, just before harvest, to determine the percentage damaged by sucking bugs. The results are summarized in table 1.

Table 1.—Summary of results of orchard experiments on the control of sucking bugs attacking peaches at Cross Anchor, S. C., during 1947.

Spray Material (Quantities per 100 gal.)	Time of Application	Peaches Damaged by Sucking Bugs
		Per Cent
DDT 1 lb.	Petal fall and shuck off	4.0
	Petal fall	4.0
	Shuck off	15.4
DDT 1 lb. plus lead arsenate, basic zinc sulfate, and sulfur mixture 16 lb. and hydrated lime 8 lb.	Petal fall and shuck off	5.2
Benzene hexachloride (gamma 3.79 per cent) 1 lb.	Petal fall and shuck off	5.4
	Petal fall	8.8
	Shuck off	11.2
Checks (untreated)	—	17.0

The petal-fall application of DDT appeared to be the most important one in the season of 1947. The shuck-off application alone gave little reduction in injury, and a two-application schedule (petal fall and shuck off) gave no better control than the petal-fall application alone. The addition of a standard plum curculio spray mixture containing lime to DDT at petal fall and shuck off did not reduce the effectiveness of the DDT.

DDT was somewhat more effective than benzene hexachloride for sucking bug control, except when applications were made at shuck off only. At that time the benzene hexachloride may have been a little more effective than DDT against pentatomids. The fact that these insects are generally more active in the trees at shuck off than earlier may account for this difference. However, most of the damage to peaches from sucking bugs in South Carolina is due to attacks earlier in the season.

TESTS OF FOG MACHINE FOR APPLYING DDT TO PEACH ORCHARDS FOR SUCKING BUG CONTROL.[2]—Tests of the fog ma-

[1] In cooperation with the South Carolina Peach Growers Association and the Clemson Agricultural College and South Carolina Agricultural Experiment Station.

[2] A. H. Yeomans and E. E. Rogers, of this Bureau, assisted with these tests and furnished and operated the fog machine.

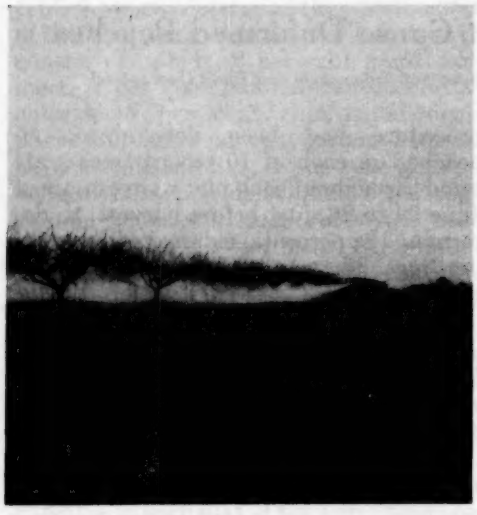

FIG. 1.—Fogging peach orchard with DDT at Woodruff, S. C.

chine for applying DDT to peach orchards for sucking bug control were conducted in two orchards at Woodruff and in one orchard at Cross Anchor, all in the southern part of Spartanburg County. In each case this method of applying DDT was compared with applications of the material with a conventional power sprayer. The orchards at Woodruff were of the Halehaven and Early Elberta (known locally as the Burnett Elberta) varieties, 6 years old, and according to the owner nearly half the 1946 crop was damaged by sucking bugs. The orchard at Cross Anchor was of the Halehaven variety, six years old, and the owner estimated that 40 per cent of the 1946 crop was damaged by sucking bugs.

The DDT fog (Fig. 1) was compared with DDT spray in two applications, at petal fall and shuck off. All sprays were applied with a 400-gallon sprayer with power take-off from a tractor at 500 pounds' pressure from four-nozzle brooms. The fog was used on about 5 acres of Halehaven peaches and about 10 acres of Early Elberta peaches at Woodruff and on 964 Halehaven trees at Cross Anchor. Areas of similar size were sprayed with DDT for comparison. The materials were prepared for use in the fog generator in the following proportions: DDT 15 pounds, xylene 4 gallons, motor oil (S.A.E. 10-W) 6 gallons, water 10 gallons. About 1.5 pounds of DDT per acre was applied with the fog machine, approximately the same quantity as was applied with the conventional sprayer.

The DDT used in the standard orchard sprayer was a 50-per cent wettable powder. In the Woodruff orchard 2 pounds of a commercial mixture per 100 gallons was used in both applications on the Halehaven variety, with the addition of a standard mixture containing lead arsenate, zinc sulfate, and sulfur.

On the Early Elbertas at Woodruff the petal-fall spray applied with a standard sprayer consisted of 1 pound of DDT, mixed and micronized with an equal weight of pyrophyllite, and 1 pint of fish-glue solution (1 pound per gallon of water) per 100 gallons. In the shuck-off application 2 pounds of a commercial 50-per cent wettable DDT was used per 100 gallons.

In the Cross Anchor orchard the same mixture was used in both applications as was used in the petal-fall spray on the Early Elbertas at Woodruff.

The results of these tests, as given in table 2, were obtained during the period June 23 to 26, and determined according to the method of scoring previously described.

The fog machine applied DDT as efficiently as did the conventional power sprayer. Statistical analyses show significant differences between the percentage of peaches damaged by sucking bugs in the treated plots and in the untreated plots. The effectiveness of the DDT applied

FIG. 2.—Machine generating DDT fog in South Carolina peach orchard.

Table 2.—Per cent of peaches damaged by sucking bugs in plots treated with DDT applied with a fog generator as compared with a conventional power sprayer, Spartanburg County, S. C., 1947.

Equipment	Halehaven Peaches		Early Alberta Peaches
	Woodruff Orchard	Cross Anchor Orchard	Woodruff Orchard
Fog generator	3.6	3.2	3.6
Conventional power sprayer	4.0	4.0	4.4
Check (untreated)	—	17.0	20.6

with a conventional power sprayer seemed to be the same for the two formulations used, and was not influenced by the addition of a commercial mix containing lead arsenate, basic zinc sulfate, and sulfur.

JARRING IN 1947 TO DETERMINE INSECTS PRESENT.—Tarnished plant bugs, other mirids, and pentatomids were caught by jarring in the untreated plot of the experimental orchard at Cross Anchor when about 85 per cent of the petals had fallen. In the same plot the following sucking bugs were caught when 50 to 75 per cent of the shucks were off: *Lygus oblineatus* (Say), *Brochymena quadripustulata* (F.), *Euschistus servus* (Say), *E. tristigmus* (Say), and *Lygaeus bicrucis* Say;[1] the pentatomids averaged 0.23 per tree.

In the untreated block at Woodruff, S. C., on an average 1.3 pentatomids and coreids per tree were caught by jarring when 75 per cent of the shucks were off. This average indicated a fairly heavy sucking bug infestation in the orchards at Woodruff that were used for the tests with the fog machine. The pentatomids were determined as *Brochymena quadripustulata*, *Euschistus tristigmus*, and *E. servus*, and the coreids as *Leptoglossus phyllopus* (L.) and *L. oppositus* (Say).[1]

When six trees each were jarred in the Halehaven and Early Elberta orchards at Woodruff on April 26, after they had received DDT fog on April 15 and 25, only two pentatomids and no coreids or mirids were taken in the Halehaven orchard, and only two pentatomids, one coreid, and one mirid in the Early Elberta orchard. An interesting incidental observation on April 26 was that Fuller rose beetles, *Pantomorus godmani* (Crotch), were collected from every tree jarred in the untreated block at Woodruff, but not one was jarred from the trees in the Halehaven and Early Elberta orchards at Woodruff that had been fogged with DDT.

SUMMARY.—Further experiments were carried on in South Carolina during 1947 to develop a satisfactory method of control of the sucking bugs that caused deformed peaches. In these experiments DDT continued to give good control. It was most effective when applied at petal fall. Little control resulted from the shuck-off application. The plum curculio spray with lime added to the DDT at petal fall and shuck off did not reduce the effectiveness of the DDT for sucking bug control. Except when applications were made at shuck off only, DDT was somewhat more effective than benzene hexachloride. The fog machine applied DDT to peach orchards for sucking bug control as efficiently as did the conventional power sprayer. Tarnished plant bugs, other mirids, pentatomids, and coreids were taken by jarring untreated trees in the experimental orchards. Very few sucking bugs were caught after the orchards had been fogged with DDT.—2-14-48.

[1] These species were determined by R. I. Sailer, of this Bureau.

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Control of Boll Weevil and Cotton Aphid with Dusts Containing Chlorinated Camphene, Benzene Hexachloride or Other New Insecticides

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Experiments conducted at the Waco, Tex., laboratory of the Bureau of Entomology and Plant Quarantine in 1946 (Ewing *et al.* 1947; Ivy *et al.* 1947) showed that chlorinated camphene and certain mixtures containing benzene hexachloride were promising all-round insecticides against the major cotton-insect pests. In 1947 field tests were conducted at several localities in Texas with these and other new insecticides against the boll weevil, *Anthonomus grandis* Boh., and the cotton aphid, *Aphis gossypii* Glov. The experimental procedure and the method of recording data were the same as had been previously reported (Ewing & Parencia 1948).

Materials.—The mixtures of benzene hexachloride with DDT or special calcium arsenate were commercial products reported to contain various amounts of active ingredients. The mixtures of regular calcium arsenate and benzene hexachloride were prepared at the laboratory. Two commercial dusts containing chlorinated camphene were used—in small-plot experiments 40 per cent of chlorinated camphene in a clay product[3] and in large-scale experiments a preparation containing 20 per cent of chlorinated camphene, 30 per cent of clay, and 50 per cent of pyrophyllite. Lower concentrations of these dusts were prepared by adding pyrophyllite or sulfur. Parathion was used as a 2-per cent dust supplied by the manufacturer. The mixtures of parathion and chlorinated camphene were prepared at the Waco laboratory from concentrated commercial dusts, 40 per cent chlorinated camphene and 25 per cent parathion. The calcium arsenate, unless otherwise stated, was the regular commercial product.

Experiments at Wharton.—One small plot and five large scale experiments were conducted near Wharton, Tex., primarily for boll weevil control. Heavy weevil infestations in this area made conditions favorable for testing insecticides against this insect. The cotton aphid also became involved in the large-scale experiments, particularly in some of the plots dusted with calcium arsenate. The treatments and experimental data are shown in table 1.

Small-plot Experiment.—In small-plot experiment 1 plots 14 rows wide and 0.2 acre in size were arranged in randomized blocks with 4 replications of each treatment. The plots were contiguous and occupied an entire isolated small field. The dusts were applied with rotary hand guns on June 28 and July 3, 8, 14, and 23. There was no injurious infestation of bollworms, *Heliothis armigera* (Hbn.), or cotton fleahoppers, *Psallus seriatus* Reut. The cotton aphid infestation was relatively light in all plots, except toward the end of the season, when there was a rapid increase in the plots treated with calcium arsenate. The aphid infestation was significantly higher in the calcium arsenate plots than in any of the others, and there were no significant differences between the other treatments.

Each insecticide reduced the boll weevil infestation significantly below that in the untreated check. The only difference between insecticidal treatments was that the benzene hexachloride containing 5 per cent of the gamma isomer gave significantly better control than the 10 per cent chlorinated camphene.

Aphids did not build up in sufficient numbers early enough in the season to cause material damage to the cotton in the calcium arsenate plots. This was not true in most of the large-scale experiments in the Wharton area, where some of the same insecticides were used. It is believed that the dust drift from some of the insecticides, especially the more potent ones, helped to control boll weevils and aphids in adjoining plots, including the calcium arsenate and check plots. If

[1] In cooperation with the Texas Agricultural Experiment Station.

[2] D. H. Alexander and H. C. Massey supervised the experiments at Wharton, Texas, and made many of the routine plot records.

[3] *Attaclay.*

Table 1.—Comparative effectiveness of chlorinated camphene, calcium arsenate, parathion, and mixtures of benzene hexachloride with DDT or calcium arsenate against boll weevils and cotton aphids.

Treatment	Rate of Application per Acre	Weevil-Punctured Squares	Aphids per Square Inch		Yield of Seed Cotton per Acre	
			Average	Maximum	Total	Gain Over Check
	Pounds	*Per Cent*	*Number*	*Number*	*Pounds*	*Pounds*
Small-plot experiment 1 at Wharton (5 effective applications, June 28 to July 23)						
Calcium arsenate	10	23	3.3	14.6	950	154
Benzene hexachloride:						
Gamma 3% plus DDT 5%	9	22	0.1	0.2	961	165
Gamma 5%	11	12	0.1	0.1	914	118
Chlorinated camphene:						
20%	11	21	0.1	0.4	906	110
10%	13	31	0.2	0.7	858	62
Untreated check	—	62	0.3	1.1	796	—
Difference required for significance, 5% level	—	11.2	0.7	—	105	—
Large-scale experiment 2 at Wharton (7 effective applications, June 27 to July 29)						
Calcium arsenate	13	50	5.6	17.0	1720	360
Chlorinated camphene						
20%	12	32	0.2	0.6	1899	539
10%	13	30	0.1	0.5	2136[1]	776
Untreated check	—	84	0.1	0.5	1360[1]	—
Large-scale experiment 3 at Wharton (7 effective applications, June 27 to July 29)						
Calcium arsenate	13	35	7.6	21.8	1323	211
Chlorinated camphene:						
20%	14	27	0.1	0.1	2323[1]	1211
10%	13	42	0.1	0.6	1606	494
Untreated check	—	86	0.2	0.9	1112[1]	—
Large-scale experiment 4 at Wharton (5 effective applications, June 24 to July 17)						
Calcium arsenate	9	18	9.0	28.0	1293	318
Chlorinated camphene:						
20%	10	28	1.4	4.6	1433	458
10%	10	35	1.2	3.8	1361	386
Untreated check	—	63	0.6	2.2	975	—
Large-scale experiment 5 at Wharton (5 effective applications, June 24 to July 17)						
Calcium arsenate	9	42	8.6	20.2	1385	553
Chlorinated camphene 10%	11	51	1.6	3.7	1364	532
Untreated check	—	74	1.9	5.2	832	—
Large-scale experiment 6 at Wharton (2 effective applications, June 27 and July 16)						
Calcium arsenate	7	13	0.6	1.8	916	224
Chlorinated camphene 10%	8	12	0.3	0.8	1139	447
Untreated check	—	50	0.1	0.4	692	—
Small-plot experiment 7 at Waco (5 effective applications, June 14 to July 14)						
Calcium arsenate	11	16	0.4	0.9	690	195
Chlorinated camphene:						
20%	10	17	0.1	0.1	958	463
10%	10	20	0.1	0.2	866	371
Untreated check	—	33	0.1	0.1	495	—
Difference required for significance, 5% level	—	8	0.2	—	136	—
Small-plot experiment 8 at Waco[2] (2 effective applications, July 9 and 14)						
Calcium arsenate	9	4	0.02	0.06	676	−152
Benzene hexachloride:						
Gamma 3% plus DDT 5%	10	3	0.01	0.02	755	− 73
Gamma 2% plus DDT 5%	9	4	0.02	0.06	772	− 56
Gamma 3%	10	4	0	0	674	−154
Parathion 2%	9	9	0.01	0.04	695	−133
Untreated check	—	19	0.01	0.01	828	—
Difference required for significance, 5% level	—	5.4	—	—	—	—
Small-plot experiment 9 at Waco (8 effective applications, July 10 to August 9)						
Calcium arsenate	13	1	7.6	25.9	965	57
Benzene hexachloride:						
Gamma 2% plus regular calcium arsenate	13	2	0.3	1.2	905	−3
Gamma 1% plus regular calcium arsenate	13	1	2.5	6.8	936	28
Gamma 2% plus special calcium arsenate	12	1	0.3	1.1	991	83
Gamma 1% plus special calcium arsenate	12	2	0.5	2.3	978	70
Untreated check	—	9	0.3	1.6	908	—
Difference required for significance, 5% level	—	2	1.4	—	—	—
Small-plot experiment 10 at Waco (6 effective applications, September 4 to 27)						

Table 1.—(Continued)

Treatment	Rate of Application per Acre	Weevil-Punctured Squares	Aphids per Square Inch		Yield of Seed Cotton per Acre	
			Average	Maximum	Total	Gain Over Check
Calcium arsenate	12	9	1.5	5.2	—	—
Chlorinated camphene:						
20%	11	10	0.1	0.3	—	—
20% plus parathion 2%	12	14	0.1	0.3	—	—
20% plus parathion 1%	12	9	0.1	0.2	—	—
10% plus parathion 2%	13	12	0.1	0.4	—	—
Untreated check	—	40	0.1	0.2	—	—
Difference required for significance, 5% level	—	7	0.2	—	—	—

[1] Fertility of soil and potential production somewhat greater in these plots than in the other two of this experiment.
[2] Losses in yield in this experiment due to increased bollworm damage in dusted plots.

this was true, then the plots were probably too small and too compactly arranged to permit proper evaluation of the different insecticides in increasing or controlling aphids or in controlling boll weevils. Each insecticide except the 10 per cent chlorinated camphene significantly increased the yield over the check, and there were no significant differences between insecticidal treatments.

LARGE SCALE EXPERIMENTS.—In the large-scale experiments the treated plots ranged from 48 to 180 rows in width and from 3 to 11 acres in size. The check plots were smaller, ranging in width from 30 to 36 rows and in size from 2 to 5 acres.

In experiments 2 and 3 the first four applications were made with a 6-row engine-driven machine mounted on a 2-wheel cart and drawn by a tractor and the last three were made by airplane because the cotton was too large for satisfactory dusting with ground equipment. The dusts in experments 4, 5, and 6 were applied with 6-row tractor-attachment machines. Although these plots were large enough to permit experiments approximating practical farm operations, in some experiments there was considerable drift of dust into adjoining plots and considerable interplot movement of insects, particularly of aphids, which no doubt affected the insect control and yield records. However, the results of these experiments give a much better index of the practical value of insect control secured from the various insecticides than do the results from the small-plot experiment. Entire plots were harvested for the yield records.

Experiment 2 was conducted on the same farm as large-scale experiment 3 on plots separated by approximately 400 yards, and the soil was more fertile than the fields where the other experiments were located. When these experiments were begun, it was thought that the soil fertility of all plots of the same experiment was strictly comparable. Before the experiments were completed, however, it was learned that in experiment 2 the plots dusted with 10 per cent chlorinated camphene and the check plot had been planted to a legume the previous year, and were therefore more fertile and capable of producing more cotton than the plots treated with calcium arsenate and 20 per cent chlorinated camphene. The latter plots were adjacent and the potential production of the land was, as far as known, the same. In experiment 3 the plot dusted with 20 per cent chlorinated camphene and the check plot had previously been planted to cabbage and heavily fertilized with superphosphate, so that the potential production of these plots was higher than for the plots treated with calcium arsenate and 10 per cent chlorinated camphene. As far as is known in the other experiments at Wharton the land and potential production of cotton in all plots were strictly comparable.

In experiments 2 and 3 the first three applications of all insecticides were at the rate of approximately 10 pounds per acre. On July 11 the rate was increased to approximately 12 to 15 pounds per acre to take care of a threatening bollworm infestation and an extremely heavy late-season infestation of migrating weevils. The cot-

ton grew so rank and continued fruiting so late that it was very attractive to weevils and acted more or less as a trap crop for late-season migrating weevils. No bollworm injury developed and there was no fleahopper damage. Aphids caused considerable shedding of leaves and some damage in the plots treated with calcium arsenate. At no time was there any aphid damage or even an indication of aphid build-up in any of the plots dusted with chlorinated camphene.

Chlorinated camphene was effective in controlling the boll weevil. As explained above, yield records are not strictly comparable between all plots in each experiment owing to differences in soil fertility. In strictly comparable dusted plots, however, the use of 20-per cent chlorinated camphene produced a gain over the check of 539 pounds as compared with a gain of 360 pounds from calcium arsenate in experiment 2; the use of 10-per cent chlorinated camphene produced a gain over the check of 494 pounds as compared with 211 pounds from calcium arsenate in experiment 3. No doubt a large part, if not all, of these increased gains from chlorinated camphene were due to damage by aphids in the cotton dusted with calcium arsenate.

In experiment 4 infestation records indicate that calcium arsenate gave the best control of weevils; however, the yields were greatest in plots treated with chlorinated camphene. There was a rather high infestation of aphids in the calcium arsenate plot toward the end of the season, and no doubt there was some migration of aphids from this plot into the other plots. Aphids caused some leaf shed and possibly a slight reduction in yield in the calcium arsenate plot.

In experiments 2, 3, and 4, 20 per cent chlorinated camphene gave slightly better, and 10 per cent chlorinated camphene slightly poorer control of the boll weevil than did calcium arsenate. The average percentage of punctured squares was 78 for the untreated checks, 36 for 10 per cent chlorinated camphene, 34 for calcium arsenate, and 29 for 20 per cent chlorinated camphene.

In experiments 5 and 6 somewhat better control of the boll weevil was obtained with calcium arsenate than with chlorinated camphene, the percentages of punctured squares averaging 62 for the check, 32 for 10 per cent chlorinated camphene, and 28 for calcium arsenate. Yields, however, were slightly in favor of the chlorinated camphene, the average gains over the check being 490 pounds of seed cotton per acre for 10 per cent chlorinated camphene and 388 pounds for calcium arsenate. The yields were probably influenced by aphids, although aphid infestation records were not continued long enough in experiment 6 to show damage in the calcium arsenate plot.

EXPERIMENTS AT WACO.—The plots of experiment 7 were 20 rows wide and 0.2 acre in size and arranged in randomized blocks, with two replications of each treatment in 1 field and two replications in another field on the same farm. There was no aphid or bollworm damage in these plots. Fleahoppers reached a peak of 32 per 100 terminals in the check plot and probably caused light damage. As a result of a sudden migration of fleahoppers, the infestation approached the damage point in all the dusted plots on July 3. Each insecticide reduced the fleahopper infestation significantly below that of the check, and at both concentrations chlorinated camphene gave significantly better control than calcium arsenate.

Each insecticide reduced the boll weevil infestation significantly below that of the check and there was no significant difference between treatments. Each treated plot produced significantly more cotton than the check plot, both the 10 and 20 per cent chlorinated camphene being significantly better than calcium arsenate. There was no significant difference between the two concentrations of chlorinated camphene.

In experiment 8 only two dust applications were made prior to July 15, because the boll weevil infestation was light. All treatments reduced the infestation significantly below that in the check. Both calcium arsenate and the benzene hexachloride dusts were superior to parathion in controlling the boll weevil, but the mixture of DDT and benzene hexachloride containing 3 per cent of the gamma isomer was the only treatment that reduced the infestation significantly below that in the plots dusted with parathion.

The dusts, which were applied just prior to a bollworm invasion, caused an increase in the bollworm infestation and damage. Boll-injury records made on July 30

showed increased bollworm infestations ranging from 45 per cent above the check for the plot dusted with DDT-benzene hexachloride mixture (2 per cent gamma) to 124 per cent for the plot dusted with parathion. On July 18, 5 per cent DDT (not reported in table) was applied to all plots for bollworm control, but, because there was a persistent light infestation, no subsequent dusting was done, with resultant losses in yields from each treatment.

Two small-plot experiments (9 and 10) were conducted at Waco, primarily for aphid control. The plots were arranged in randomized blocks with four replications of each treatment. In experiment 9 the plots were 16 rows wide and 0.2 acre in size, and in experiment 10 they were 14 rows wide and 0.14 acre in size.

In experiment 9 there was a rather heavy infestation of aphids in the plots treated with calcium arsenate alone. The addition of benzene hexachloride to both the regular and the special calcium arsenate seemed to aid materially in controlling the aphid. There was no significant difference between the regular and the special calcium arsenate plus 2 per cent of the gamma isomer, the special calcium arsenate containing 1 per cent of the gamma isomer, and the check, but in the plot treated with the regular calcium arsenate plus 1 per cent of the gamma isomer the infestation was significantly higher. The yields showed no significant difference between treatments.

In experiment 10 aphids did not build up sufficiently for an evaluation of mixtures of parathion and chlorinated camphene in controlling this insect.

OTHER EXPERIMENTS.—Several large-scale experiments were conducted near Waco, Cameron, Hearne, and Honey Grove, Texas, for boll weevil and aphid control, but they are not reported in detail in this paper. Where chlorinated camphene or the mixture of 5 per cent DDT and benzene hexachloride containing 3 per cent of the gamma isomer was used, satisfactory control of both insects was obtained. In two or three experiments pre square dusting with these insecticides for control of all early-season injurious insects showed up to good advantage.

SUMMARY.—Several experiments were conducted in Texas in 1947 to determine the value of some of the newer insecticides against the boll weevil, *Anthonomus grandis* Boh., and the cotton aphid, *Aphis gossypii* Glov. In a small-plot experiment at Wharton the yields of cotton dusted with calcium arsenate, two mixtures of DDT and benzene hexachloride, and two concentrations of chlorinated camphene showed no significant differences. However, the least weevil control and the lowest yield were obtained from the 10 per cent chlorinated camphene plots. Cotton aphids caused no damage in any of the dusted plots.

In five large-scale experiments in the same general location 20 per cent chlorinated camphene gave slightly better control, and the 10 per cent chlorinated camphene gave slightly poorer control, than calcium arsenate. Aphids caused considerable damage in most of the plots dusted with calcium arsenate, but not in those dusted with chlorinated camphene. As a result of the combined control of both weevils and aphids, both strengths of chlorinated camphene effected higher yields than the calcium arsenate. In experiments in which the dusted plots were strictly comparable, 20 per cent chlorinated camphene produced a gain over the check of 539 pounds as compared to a gain of 360 pounds from calcium arsenate, and 10 per cent chlorinated camphene a gain of 494 pounds as compared with 211 pounds from calcium arsenate.

In a small-plot experiment at Waco, where both weevils and fleahoppers were causing damage, plots treated with calcium arsenate and 10 and 20 per cent chlorinated camphene produced significantly more cotton than the check. The chlorinated camphene dusts were significantly better than the calcium arsenate. There was no significant difference in yield between the two concentrations of chlorinated camphene.

In another small-plot experiment at Waco there was some indication that a special calcium arsenate was more compatible with benzene hexachloride, especially at 1 per cent of the gamma isomer than was the regular calcium arsenate.

When parathion mixed with chlorinated camphene was dusted on cotton, the two insecticides appeared to be compatible, but indications were that 2 per cent of parathion was not effective against the boll weevil.

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Insecticide Tests in Field Plots for Control of the Sweetpotato Weevil

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Farm sanitation has for many years been the standard method of controlling the sweetpotato weevil (*Cylas formicarius elegantulus* (Sum.) in the field. It has been recognized, however, that an effective remedial measure involving the application of insecticides during the growing season of the crop would be a valuable supplement to the control program. The possibility of such remedial measures has been indicated by toxicity experiments demonstrating that the adult insect can be killed under laboratory conditions with arsenicals and other stomach poisons.

Field-plot experiments were therefore begun in 1938 to determine whether field infestations of the sweetpotato weevil could be effectively and economically controlled with insecticides, and if so to develop suitable schedules of application. These experiments were conducted in St. Landry and East Baton Rouge perishes in Louisiana. The plots were arranged in either latin squares or randomized blocks each plot usually consisting of 4 rows 50 feet long, containing approximately 800 square feet.

During the first few years of these experiments the schedule of applications was varied. Some plots received two to four applications in the early part of the growing season, some plots two to four applications late in the summer and early fall, and others applications at 14-day intervals throughout the growing period. Insecticides in the early experiments were synthetic cryolite, with and without a sticker consisting of a proprietary wetting agent mixed with soybean flour and casein glue; and basic calcium arsenate, alone and mixed with 4 per cent of soybean flour plus 1 per cent of casein glue.

In the 1938 experiments the basic calcium arsenate treatments were significantly better than the cryolite treatments but the stickers were not beneficial. The 14-day applications made throughout the season were significantly better than the other schedules, although all were beneficial as compared with the untreated checks.

In the 1939 experiment basic calcium arsenate was used at dosages of 5 and 10 pounds per acre, and the schedules were two early applications, two late applications, and applications at 14-day intervals throughout the season. All the schedules reduced the infestation, and there was very little difference between the light and heavy dosages. The late applications tended to be better than the early applications, but best results were obtained when the applications were made throughout the growing period.

During 1940 and 1941 the experiments were limited to the study of poisoned baits. In 1940 promising results were obtained in preliminary tests with a mixture of 20 parts of ground sweetpotato, 1 part of paris green, and 0.4 per cent (by weight) of sodium benzoate. This bait was therefore tested on a larger scale in 1941. Field plots consisting of 3 rows 25 feet long were used with 4 replicates. The bait was broadcast at weekly intervals at the rate of 120 pounds per acre until July 14, and 180 pounds per acre thereafter. The bait treatment reduced the weevil infestation in the plants but not in the sweetpotatoes. The foliage was severely burned, particularly after the vines attained rank growth, by particles of the bait lodging on the large leaves.

[1] In cooperation with the Louisiana Agricultural Experiment Station, and the Louisiana Department of Agriculture and Immigration.

In 1942 tests were conducted on an infested farm, with calcium arsenate dust applied at weekly intervals for one month, weekly for 2 months, and biweekly for two months. There was no significant difference in infested potatoes between the three insecticide treatments, but all treatments were significantly better than the untreated check. On the check plots 9.41 per cent of the field-run potatoes were infested and on the plots receiving biweekly applications for 2 months, which had the smallest actual infestation, 0.1 per cent were infested.

In 1943 duplicate experiments were conducted at Opelousas and Baton Rouge, La.,[1] each experiment consisting of six treatments arranged in a latin square. The treatments were calcium arsenate applied weekly for 1 month and biweekly for 2 months, cryolite biweekly for 2 months, and a mixture of equal parts of calcium arsenate and cryolite weekly for 1 month and biweekly for 2 months. The infestation at Opelousas was very light, but that at Baton Rouge was somewhat heavier. At the end of September, considering both experiments, together, there was no difference between any of the treatments, including the check. At a second sampling made the middle of November, the infestation in the undusted plots was greater than in those to which calcium arsenate and calcium arsenate plus cryolite were applied biweekly for 2 months.

During 1944 two experiments were conducted, one on a commercial sweetpotato farm where the infestation was too light for beneficial results, and the other on Experiment Station plots. At the Experiment Station the treatments consisted of calcium arsenate applied in three biweekly schedules—for 2 months, all season, and from July 15 to the end of the season—and potassium fluosilicate applied biweekly all season and 10 per cent DDT dust applied monthly all season. Similar results were obtained with the three calcium arsenate schedules, all of which were better than the potassium fluosilicate and DDT schedules. There were more infested potatoes, by weight, on the plots treated with potassium fluosilicate and DDT than on the untreated polts. The heavy infestation on the DDT-treated plots was a distinct disappointment, since the laboratory tests had indicated that DDT might be very effective in the field.

During 1945 the infestation was so light that worth while results were not obtained.

In 1946 the treatments consisted of calcium arsenate plus 1 per cent of light lubricating oil applied biweekly at 20 pounds and monthly at 40 pounds per acre; 5 per cent DDT plus 1 per cent of oil applied biweekly all season at 10 pounds and from August 1 to the end of the season at 20 pounds per acre; undiluted *Ryania* applied biweekly all season at 20 pounds per acre; benzene hexachloride containing 2.9 per cent of gamma isomer applied biweekly all season at 10 pounds per acre; and a cultural treatment consisting of high hilling when the crop was laid by. The only effective treatments were the two calcium arsenate treatments and the cultural treatment.

The best treatment, calcium arsenate applied biweekly, resulted in a reduction of 19 bushels of infested potatoes per acre, but since there was no consistent increase in yield of uninfested potatoes, the treatment is of doubtful value.

In 1947 most of the insecticides were applied biweekly throughout the growing season, there being nine applications. The greatest reduction of field-run weevil-infested sweetpotatoes, 87 per cent or 24 bushels per acre, was obtained with calcium arsenate at 10 pounds per acre. Although these results again showed that field infestations of the weevil can be reduced, they probably did not justify the nine applications that were necessary. Benzene hexachloride dust containing 5 per cent of the gamma isomer applied at 20 pounds per acre was almost as effective as the calcium arsenate treatment. Calcium arsenate applied monthly at 20 pounds per acre was almost as effective as when applied biweekly at 10 pounds. Promising results were obtained with 20 pounds per acre of 10 per cent chlorinated camphene and with a cultural treatment consisting of high hilling of the plants at the last cultivation. Treatments that were not effective were 5 per cent DDT at 20 pounds per acre, and a DDT-xylene emulsion applied as a concentrated spray monthly at 1 pound DDT per acre for two

[1] The experiment at Baton Rouge was conducted by E. H. Floyd, Louisiana Agricultural Experiment Station, but the sampling and infestation records were made by the authors of this paper after Mr. Floyd's entry into military service.

Table 1.—Comparative effectiveness of calcium arsenate and DDT for the control of the sweetpotato weevil, in field-plot experiments.

Insecticide Dusts	Dust Mixture per Acre Application	Intervals	Season	Weevil-Infested Sweetpotatoes Produced	
	Pounds	*Days*		*Pounds*	*Per Cent*
		Experiments in 1944			
Calcium arsenate	10	14	First 2 months	58.6	6.2
	10	14	All	23.6	2.4
	10	14	After July 15	39.4	4.3
DDT 10 per cent	10	28	All	111.6	10.9
		Experiments in 1945			
Calcium arsenate plus oil 1 per cent	10	14	All	.0	.0
	20	14	All	1.3	.3
	40	28	All	.3	.1
DDT 5 per cent plus oil 1 per cent	40	14	All	1.5	.3
	20	14	After Aug. 1	4.7	1.4
		Experiments in 1946			
Calcium arsenate plus 1 per cent oil	20	14	All	6.2	1.3
	40	28	All	11.7	2.4
DDT 5 per cent plus 1 per cent oil	10	14	All	44.4	8.4
	40	14	After Aug. 1	27.2	5.5
		Experiments in 1947			
Calcium arsenate	10	14	All	13.8	1.8
	20	28	All	21.8	2.8
DDT 5 per cent	20	14	All	83.7	10.2
DDT emulsion[1]	1–2[1]	28	All	106.5	13.6

[1] This was a spray treatment and the quantity per acre refers to technical DDT.

applications and 2 pounds for the last three applications.

A comparison of the effectiveness of calcium arsenate and DDT treatments, where the two have been tested in the same experiments for several years, is shown in table 1.

SUMMARY—Field-plot experiments were conducted in St. Landry and East Baton Rouge parishes in Louisiana during a 10-year period to develop effective methods of controlling field infestations of the sweetpotato weevil, *Cylas formicarius elegantulus* (Sum.) with insecticides. Dust mixtures tested included calcium arsenate, cryolite, 5 and 10 per cent DDT, potassium fluosilicate, *Ryania*, benzene hexachloride (2.9 and 5 per cent of gamma isomer), and 10 per cent chlorinated camphene.

Calcium arsenate dust was the most effective insecticide tested. For best results it was necessary to apply the calcium arsenate at biweekly intervals throughout the growing period. It is doubtful whether the results justified the 8 to 10 applications that were necessary.

A DDT-emulsion spray was no more effective than DDT dust.—2-26-48

Effects of Benzene Hexachloride and DDT Upon Parasitization of the Oriental Fruit Moth

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The increasing popularity of residual organic insecticides for the control of peach-infesting insects has caused considerable concern as to the possible adverse effects of these materials upon important natural enemies of these pests. In Ohio, for example, many peach growers are reluctant to use DDT to control the oriental fruit moth for fear of eliminating certain parasite species, particularly *Macrocentrus ancylivorus* Rohwer. The distribution and establishment of this important parasite has been greatly accelerated by artificial means at a considerable expenditure of effort and funds. Obviously it would be undesirable to use an insecticide to control fruit moth if the poison also eliminated or seriously handicapped its parasite one of the most important components of environmental resistance.

Smith & Driggers (1946) and Peterson (1946) have shown that DDT is very toxic to some important parasites in the laboratory. Wheeler & LaPlante (1946) found that DDT materially reduced the parasite population in a treated section of a peach orchard. There have also been reports that benzene hexachloride possesses greater toxicity to honeybees and other Hymenoptera than does DDT. The present study was made to determine the effects of grower applications of benzene hexachloride and DDT upon parasite activity in several orchards representing various geographic sections of Ohio.

Forty paired orchards were selected for sampling, the two members of each pair being similar in geographic location and growth characteristics. One of the orchards in each pair represented a treatment orchard where the grower applied either or both of the materials under consideration while the other served as a check in which neither of the materials was used. Sampling was done by clipping infested twigs from five trees in each of four widely separated areas in the orchard. When this method failed to provide an adequate sample, additional twigs were obtained wherever available in any part of the orchard. The number of infested twigs obtained at each sampling interval ranged from 1 to 89 with an average of 16.7 twigs per collection. Each of the orchards was sampled an average of 3.4 times during the season. An attempt was made to secure samples at weekly intervals in Erie, Ottawa and Sandusky Counties and samples of each brood in other parts of the State.

Larval parasitization was determined by rearing fruit moth larvae and larval parasites to maturity according to the method described by Blackburn (1946). Total parasitization, or the percentage of host larvae parasitized by all species of parasites, has been used as a criterion for evaluating the influence of insecticidal application on parasitization. In the orchards sampled two species of *Macrocentrus* dominated the parasite populations. *M. ancylivorus* comprised 84.9 per cent and *M. delicatus* 11.5 per cent of the total collections of parasites.

EFFECT OF BENZENE HEXACHLORIDE ON PARASITIZATION.—Benzene hexachloride was used in nine orchards for the control of plum curculio. Most of the applications were made in May or early June prior to the period of peak emergence of parasites. Samples were taken from these treated orchards as well as from nine untreated orchards at approximately the same time.

Table 1 shows the total parasitization in the nine pairs of orchards. The percentages of parasitization varied considerably and would seem to indicate that parasite populations were higher in orchards treated with benzene hexachloride than they were in the check orchards. However, a statistical analysis shows the differences do not approach significance even at the 5 per cent level.[2] There is certainly no evidence apparent in these data to indicate that benzene hexachloride applied for the control of plum curculio had any deleterious influence upon total parasitization of the oriental fruit moth.

EFFECT OF DDT ON PARASITIZATION.—Eleven of the orchards sampled were

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[2] The authors are indebted to Mr. Robert S. Gardner of the Statistics Laboratory, Ohio State University for the analyses.

Table 1.—Total parasitization in orchards treated with benzene hexachloride and in untreated orchards.

County	Benzene Hexachloride		Untreated	
	Total[1] emergence	Per cent parasitization	Total[1] emergence	Per cent parasitization
Hamilton	22	0.0	17	41.2
Hamilton	23	13.0	68	17.6
Lorain	91	78.0	22	72.7
Lorain	33	66.7	25	48.0
Mahoning	25	60.0	11	72.7
Columbiana	38	65.8	27	51.8
Ottawa	298	29.9	267	11.8
Ottawa	54	74.1	66	43.9
Ottawa	11	27.4	37	51.4
Average	66.1	45.0	60.0	27.4

[1] Total emergence refers to actual numbers of both moths and parasites.

treated with DDT in 1947. This afforded opportunity for determining the influence of DDT applications upon parasite populations during the period of treatment. Growers began applications for the control of oriental fruit moth in the middle or latter part of July and continued applications to late August. The number of spray applications in most cases was limited to one or two but in one orchard four sprays were applied. A 5 per cent DDT dust was used in several orchards where three to four treatments were made. Parasitization records for the paired orchards are presented in table 2.

Table 2.—Parasitization in orchards treated with DDT in 1947 and in untreated orchards.

County	DDT Orchards		Check Orchards	
	Total[1] emergence	Per cent parasitization	Total[1] emergence	Per cent parasitization
Butler	17	6.3	12	8.3
Columbiana	27	51.8	11	72.7
Erie	118	39.8	111	76.6
Erie	155	16.6	226	48.7
Hamilton	22	0.0	17	41.2
Hamilton	14	7.1	7	71.4
Lawrence	29	0.0	27	44.4
Ottawa	71	11.3	152	55.3
Ottawa	75	18.7	37	86.5
Sandusky	22	40.9	8	75.0
Sandusky	48	31.5	25	80.0
Average	54.3	22.6	57.5	58.5

[1] Total emergence refers to actual numbers of both moths and parasites.

The differences in these populations are significant at the 1 per cent level and show that parasites are definitely affected by applications of DDT. The nature of this effect is revealed in the following comparison: In 7 of the 11 pairs of orchards, frequent collections were made throughout the twig-infesting season. These collections made it possible to compare the relative amount of parasitization both before and after the application of DDT. The percentages of parasitization determined from these collections are summarized in table 3.

Table 3.—Parasitization in orchards before and after DDT applications compared with parasitization in orchards not treated with DDT.

County	DDT Orchards[1]		Check Orchards	
	Early parasitization	Late parasitization	Early parasitization	Late parasitization
Erie	34.0	39.8	50.0	76.6
Erie	25.0	16.8	38.7	48.7
Hamilton	38.7	7.1	25.0	71.4
Ottawa	10.1	11.3	14.5	55.3
Ottawa	8.5	18.7	42.9	86.5
Sandusky	12.5	40.9	0.0	75.0
Sandusky	50.0	31.3	100.0	80.0
Average	21.9	24.1	35.9	73.4

[1] Early parasitization refers to collections obtained before initial DDT applications and late parasitization refers to collections made during application periods.

It is evident from these comparisons that there was a marked increase in parasitization in the nontreatment orchards while that in the treated orchards remained nearly constant, the percentages of parasitization not being materially reduced by the treatment. This fact may account to some extent for the ability of parasites to repopulate orchards the year following insecticide application. Probably the parasite population surviving treatment is also supplemented by the infiltration of parasites from alternate hosts in untreated areas surrounding the orchard. Since the relative numbers of parasites are dependent upon the host density, it would be reasonable to assume that DDT-treated orchards would have a lower host density and consequently lower rates of parasitization. However, host density records in seven pairs of orchards in this group show that the host index was higher in the DDT treated orchards than in the untreated ones, therefore, this objection to the interpretation of results may be discounted. The greater host density in treated orchards is attributable to relatively high first-brood populations and the failure of 5 per cent DDT dusts in some orchards to obtain adequate control of twig-infesting larvae.

The effects of DDT on parasitization of second-brood, twig-infesting larvae are readily observed in figure 1 where seven pairs of orchards are compared. The peak parasitization of second brood larvae oc-

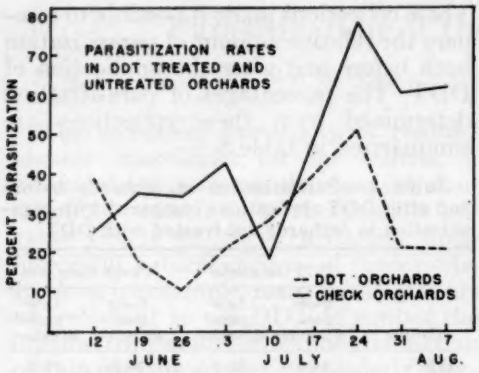

FIG. 1.—Parasitization of twig-infesting larvae in DDT treated and untreated orchards.

curred on July 24 after initial applications of DDT had been made. During this critical period, when high rates of parasitization greatly reduce the eventual numbers of fruit-infesting larvae, parasitization in treated orchards was reduced by approximately 36 per cent. This reduction in parasitization would be of little importance if DDT always gave commercial control of the fruit moth, but there seems to be evidence that at certain levels of concentration DDT acts as a selective insecticide. In other words, some residues may be very toxic to parasites and have little effect upon oriental fruit moth. If this is true, the residues of 5 per cent DDT dust applications more nearly approach this selective level than do spray residues of the 50 per cent wettable powders. In experimental plots where DDT residues were studied in relation to formulation, it was found that an initial deposit of 2.9 micrograms per square centimeter on peach foliage was obtained with 5 per cent dusts while a spray of 50 per cent wettable powder at the rate of 2 pounds per 100 gallons gave an initial deposit of 8.4 micrograms.[3]

In one orchard, representing the extremely detrimental effects of heavy DDT applications, a colony of 1379 *Macrocentrus ancylivorus* was released on June 28. Following liberation, four applications of 50 per cent wettable powder at the rate of 2 pounds per 100 gallons were made on July 11, July 25, August 11 and August 26. A total of 28 fruit moth larvae were collected on three sampling dates after initial application. Only 6.6 per cent of the larvae were parasitized and this figure represents a single specimen each of *M. ancylivorus* and *M. delicatus*.

Seven of the orchards had been treated with DDT in 1946. These were used to determine the effect of the insecticide upon parasitism the following year. Each of the treatment orchards was again paired with a non-treatment orchard where DDT was not used in 1946. In some cases orchards which were treated in 1946 also received DDT in 1947. These were paired with orchards which were untreated in 1946 but received similar schedules of DDT in 1947.

A comparison of the parasitization in the two classes of orchards appears in table 4. The differences in 1947 percentages of parasitization between treated and untreated groups are non-significant. These data show that the use of DDT in 1946 for the control of the oriental fruit moth did not eliminate but may have partially reduced the parasite populations the following year.

Table 4.—Total parasitization in 1947 of orchards treated with DDT in 1946 and in orchards untreated in 1946.

County	Orchards Treated With DDT in 1946		Orchards Not Treated With DDT in 1946	
	Total emergence	Per cent parasitization	Total emergence	Per cent parasitization
Erie	33	51.5	57	71.9
Erie	318	36.2	195	71.8
Hamilton	68	17.6	17	41.2
Mahoning	38	65.8	25	60.0
Mahoning	6	16.7	8	37.5
Ottawa	46	45.7	221	42.5
Ottawa	157	35.0	100	59.0
Average	95.1	36.9	89.0	57.6

SUMMARY.—Studies were conducted in 40 Ohio orchards to determine the effects of benzene hexachloride and DDT upon parasitization of twig-infesting larvae of the oriental fruit moth. Benzene hexachloride, when used for control of the plum curculio, apparently did not reduce parasite activity in a group of nine treated orchards. In orchards where DDT was applied for control of the oriental fruit moth in 1947 the parasitization was much lower than those in non-treatment orchards and these differences in parasitization were statistically highly significant. Furthermore, rates of parasitization increased approximately 100 per cent during the season in the non-treatment group

[3] DDT spray residue analysis conducted by Mr. J. E. Fahey, Division of Insecticide Investigations, Vincennes, Indiana.

while an increase of only 10 per cent was recorded for the treatment group. The use of DDT during the season of 1946 did not eliminate but may have partially reduced the parasite populations or rate of parasitization the following year.

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New Insecticides for Control of Plum Curculio on Peach

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In 1947 preliminary cage tests were conducted at Fort Valley, Ga., to determine the effect of certain new insecticides on the plum curculio, *Conotrachelus nenuphar* (Hbst.) and on peach fruit and foliage, in comparison with that of standard lead arsenate sprays. Benzene hexachloride, which appeared to be a promising plum curculio insecticidein 1946 (Snapp 1947), and an ethylene dibromide soil treatment were also tested in replicated orchard plots.

The materials used in the tests, largely commercial products, were as follows:

Chlordan, wettable powder, 47.2 per cent
Chlorinated camphene (67 to 69 per cent chlorine):
  Wettable powder, 27.5 per cent
  Dust, 5 to 20 per cent
Hexaethyl tetraphosphate
Tetraethyl pyrophosphate
Ryania:
  100 per cent spray grind
  100 per cent spray concentrate
Parathion (0,0-diethyl 0-*p*-nitrophenyl thiophosphate), wettable powder, 15 per cent
Benzene hexachloride:
  Wettable powder (31.6 per cent technical benzene hexachloride) reported to contain 3.79 per cent of gamma isomer
  Wettable powder (40.3 per cent technical benzene hexachloride) containing 4.5 per cent of gamma isomer
  Miscible emulsion, 10 per cent of gamma isomer and 20 per cent of organic thiocyanate
  Dust, 1 per cent of gamma isomer

Sodium lauryl sulfate (3 ounces per 100 gallons) was used as a wetting agent in sprays prepared with the hexaethyl tetraphosphate and tetraethyl pyrophosphate concentrates. Zinc sulfate, 2 pounds and hydrated lime, 8 pounds per 100 gallons, were added to the standard lead arsenate sprays.

CAGE TESTS.—Seven series of cage tests, four in the field and three in the insectary, were conducted from April to August. Sprays were applied to peach trees with a double-acting hand spray pump at 180 to 200 pounds' pressure. Dusts were applied with a bellows-type knapsack hand duster. Wire-screen cages, each containing 25 adult plum curculios, were then placed over treated branches bearing fruit and foliage. Each cage had a cloth sleeve, which was tied at one end to a limb to hold it in place. In the insectary tests peach twigs bearing treated fruit and foliage were placed in wire-screen cages with 25 curculios.

Field series.—In the field tests overwintered curculios that had been jarred from unsprayed peach trees in April were used in a series started on April 23; overwintered curculios jarred from unsprayed peach and wild plum trees on May 12, 13, and 14 in a series started on May 14; first-generation curculios that emerged on June 8 and 9, and were not allowed to feed before the tests were started, in a series started on June 9; and first-generation curculios that had been maintained in the insectary on untreated peach fruit and foliage, after they had emerged on June 11 and 12, in a series started on July 1.

Insectary series.—In the insectary tests, first-generation curculios that emerged between June 9 and 13 were used in a series started on July 25; first-generation curculios that emerged on June 8 in a series started on August 6; and first-generation

[1] Julius P. Hollon assisted in all experiments reported in this paper.

Table 1.—Per cent mortality of plum curculio adults on indicated days after treatment with some new insecticides.

TREATMENT[1] (Quantities per 100 Gallons Unless Otherwise Indicated)	2 DAYS	3–5 DAYS	6–7 DAYS	8–14 DAYS	15–21 DAYS	22–28 DAYS
Field Series Started April 23						
Chlordan 2 lb.	—	—	100			
Chlorinated camphene:						
4 lb.	—	—	96	96	96	
20% dust	—	—	100			
Hexaethyl tetraphosphate 2 qt.	—	—	100			
Ryania, spray grind, 4 lb.	—	—	44	48	72	
Benzene hexachloride (4.5% gamma)						
4 lb.	—	—	60	64	72	
2 lb.	—	—	64	76	96	
Lead arsenate 2 lb.	—	—	36	72	92	
Checks (no treatment):	—	—	40[2]	64[2]	96[2]	
	—	—	56[2]	68[2]	100[2]	
Field Series Started May 14						
Chlordan 2 lb.	—	—	100			
Chlorinated camphene:						
4 lb.	—	—	96	100		
10% dust	—	—	100			
Hexaethyl tetraphosphate 1 qt.	—	—	100			
Ryania spray grind, 4 lb.	—	—	59	73	91	100
Benzene hexachloride (3.79% gamma):						
6 lb.	—	—	88	92	100	
3 lb.	—	—	52	60	100	
Lead arsenate 2 lb.	—	—	62	100		
Checks (no treatment):	—	—	12	12	100[2]	
	—	—	0	4	88[2]	88[2]
Field Series Started June 9						
Chlordan 1.5 lb.	100					
Chlorinated camphene:						
3 lb.	100					
5% dust	100					
Hexaethyl tetraphosphate, 0.67 qt.	—	100				
Ryania, spray grind, 4 lb.	—	0	—	48	48	
Benzene hexachloride (3.79% gamma)						
6 lb.	—	44	—	52	52	
3 lb.	—	16	16	16	16	
Lead arsenate 2 lb.	—	12	—	100		
Checks (no treatment):	—	4	8	8	8	
	—	0	0	0	0	
Field Series Started July 1						
Chlordan 2 lb.	0	—	20	40	68	88
Chlorinated camphene						
4 lb.	12	—	72	88	92	92
10% dust	4	—	68	92	100	
Hexaethyl tetraphosphate 0.67 pt.	80	—	84	84	100	
Ryania, spray concentrate, 8 oz.	0	—	4	8	92[3]	100
Parathion[1] 2 lb.	100					
Benzene hexachloride (3.79% gamma) 6 lb.	0	—	8	12	88	88
Benzene hexachloride (4.5% gamma) 2 lb.	0	—	0	0	52	68
Lead arsenate 2 lb.	0	—	0	20	32	52
Checks (no treatment):	0	—	0	0	96[3]	96
	4	—	4	8	100[3]	

[1] The chlordan, chlorinated camphene, benzene hexachloride, and parathion were wettable powders containing the proportions of active ingredient indicated earlier in the paper.
[2] Overwintered curculios that probably died from age.
[3] Fruit gone; curculios may have died from lack of suitable food.

Table 1.—(Continued)

TREATMENT[1] (Quantities per 100 Gallons Unless Otherwise Indicated)	2 Days	3–5 Days	6–7 Days	8–14 Days	15–21 Days	22–28 Days
Insectary Series Started July 25						
Chlordan 2 lb.	—	24	28	36		
Chlorinated camphene 4 lb.	—	20	40	72		
Hexaethyl tetraphosphate 1 pt.	—	64	64	64		
Parathion 2 lb.	—	100				
Benzene hexachloride (4.5% gamma) 4 lb.	—	4	12	24		
Lead arsenate 2 lb.	—	0	0	8		
Check (no treatment)	—	0	4	4		
Insectary Series Started August 6						
Chlordan 2 lb.	0	4	24	24	28	
Chlorinated camphene 4 lb.	0	0	0	12	12	
Hexaethyl tetraphosphate 1 pt.	16	—	28	28	28	
Parathion:						
2 lb.	36	100				
1 lb.	72	100				
0.5 lb.	52	100				
Benzene hexachloride (4.5% gamma) 4 lb.	0	0	0	0	8	
Lead arsenate 2 lb.	0	0	0	0	0	
Check (no treatment)	4	4	4	8	12	
Insectary Series Started August 22						
Tetraethyl pyrophosphate 1 pt.	—	76	76	76	76	80
Parathion 2 lb.	—	100				
Benzene hexachloride miscible emulsion with organic thiocyanate, used at strength of 2.5%	—	12	20	84	88	96
Check (no treatment)	—	0	0	8	12	16

curculios that emerged during the period June 14 to July 10 in a series started on August 22. All curculios were maintained in the laboratory on untreated peach fruit and foliage between the time of collection and use in tests.

The results of both series of the cage tests are given in table 1.

The most outstanding results were those obtained with parathion. The 15 per cent wettable powder, at rates of 0.5 to 2 pounds per 100 gallons of spray, killed all the plum curculio adults within 2 to 5 days. The chlorinated camphene, chlordan, hexaethyl tetraphosphate, and tetraethyl pyrophosphate are also considered promising materials. Benzene hexachloride, a material considered promising on the basis of previous tests, was not markedly more effective than lead arsenate. *Ryania* was relatively ineffective.

Residual effect of the new insecticides.—Adult plum curculios were caged on portions of peach trees at intervals after treatment to determine the residual effect of the deposits of some of the newer insecticides. The beetles used in these tests were first-generation curculios that emerged between June 4 and July 10. After emergence they were maintained in the insectary on untreated peach fruit and foliage until the tests were started. The results of these tests are given in table 2.

Spray deposits containing parathion retained their effectiveness longer than those of any of the other insecticides tested. At a concentration as high as 0.67 quart per 100 gallons hexaethyl tetraphosphate had little, if any, effect on the plum curculio after 3 days. Chlorinated camphene dust deposits also lost their effectiveness rapidly.

ORCHARD TESTS.—Benzene hexachloride was compared with lead arsenate and ethylene dibromide emulsion, the last material applied as a soil treatment, in experiments conducted under commercial peach-orchard conditions. There were 5 replications of each treatment in a latin-square arrangement of plots, each with 36 trees. Wettable sulfur, 6 pounds per 100

Table 2.—The residual effect of some new insecticides on the plum curculio.

TREATMENT[1] (Quantities per 100 Gallons Unless Otherwise Indicated)	DAYS FROM APPLICATION OF SPRAY TO CAGING OF CURCULIOS	PER CENT MORTALITY AFTER— 2 Days	3–5 Days	6–7 Days	8–14 Days	15–21 Days
	Sprays Applied June 9					
Chlordan 1.5 lb.	2	—	—	32	92	92
Chlorinated camphene:						
3 lb.	2	—	—	12	72	76
5% dust	2	—	—	8	20	32
Hexaethyl tetraphosphate 0.67 qt.	3	—	—	4	8	8
	Sprays Applied July 1					
Parathion 2 lb.	2	—	100			
	6	8	92	—	100	
	14	4	—	40	96	96
Chlorinated camphene 10% dust	14	0	—	12	28	40
Hexaethyl tetraphosphate 0.67 pt	14	0	—	0	24	
	Sprays Applied July 25					
Parathion 2 lb.	3	52	100			
	7	—	100			
	10	52				
	Sprays Applied August 6					
Parathion						
2 lb.	5	80	100			
	9	—	48	100		
	15	—	24	96	100	
	23	—	92	100		
	30	—	0	4	60	76
1 lb.	5	4	20	80	84	
0.5 lb.	5	8	16	36	40	
	Sprays Applied August 22					
Parathion						
2 lb.	3	100				
	5	80	100			
	10	88	100			
	14	—	92	96	100	
	24	4	8	28	40	
Checks (untreated):						
Curculios caged July 15		0	—	4	76[2]	96[2]
Curculios caged Aug. 11		0	0	4	8	
Curculios caged Aug. 25		0	0	0	0	

[1] The chlordan, chlorinated camphene, and parathon were wettable powders containing the proportions of active ingredient indicated earlier in the paper.
[2] No fruit present; curculios may have died from lack of suitable food.

gallons, was included in all sprays applied 2 weeks after shuck-off and 4 weeks before harvest. Zinc sulfate, 2 pounds and hydrated lime, 8 pounds, were included in all lead arsenate sprays. When the fruit was harvested, each peach was cut open to determine the percentage infested with the plum curculio. The results are given in table 3.

A statistical analysis of the results of these tests showed that the benzene hexachloride schedules were not significantly better than the lead arsenate, which failed to give satisfactory control of the plum curculio. An application of benzene hexachloride on infested drops, in combination with the regular schedule of lead arsenate sprays on the fruit, seemed to reduce slightly the curculio infestation in the harvested fruit, but this difference was likewise not significant. The ethylene dibromide treatment was significantly less effective than any of the other treatments

Table 3 shows that the percentage of infested peach drops was low where benzene hexachloride (4.5 per cent gamma) was used at the rate of 4 pounds in 100 gallons in 3 applications, followed by 1 application of lead arsenate. Apparently the benzene hexachloride prevented early-season drop, as 7630 peaches were harvested from 20 trees that received the 3

applications as compared with 3360 peaches from 20 trees receiving the ethylene dibromide treatment and 5880 peaches from 20 trees receiving the straight lead arsenate schedule.

Treatment of Peach Drops with Benzene Hexachloride.—On May 2 two lots of peach drops that had been collected the previous day were sprayed with benzene hexachloride (4.5 per cent gamma) at the rates of 4 and 8 pounds per 100 gallons of water. For the spraying operation, the drops were spread out on the ground in a layer one peach deep to simulate orchard conditions. After treatment they were placed in racks in the laboratory for observations on larval emergence. An unsprayed lot was placed in another peach-drop rack to serve as a check.

Plum curculio larvae began to emerge from the drops on May 3, a day after the experiments were started. They were removed and counted daily until June 4, after which there was no further emergence from the untreated drops. The number of larvae emerging from one bushel of drops was 2540 with the 4-pound treatment, 1253 with the 8-pound treatment, and 11,393 for the untreated peaches.

The difference in larval emergence from the three lots of drops was not pronounced until 4 days after treatment. This indicates, in confirmation of last year's results, that several days are required for sufficient penetration of the benzene hexacloride into the peach drops to kill the larvae.

Some of the larvae that emerged from the treated and untreated drops were placed in separate pupation boxes for observations on the effect of the benzene hexachloride treatment on the development of adults. Adults began to emerge from these boxes on June 3, and emergence continued until June 26.

From the drops treated with 4 pounds of benzene hexachloride per 100 gallons, 48.8 per cent of 750 larvae reached the adult stage, and from the drops treated with 8 pounds of this material per 100 gallons, 28.5 per cent of 589 larvae became adults. From 750 larvae taken from untreated drops, 76.8 per cent reached the adult stage.

Even though some of the larvae managed to emerge from the treated drops before there was sufficient penetration of benzene hexachloride to kill them, the insecticide was partially successful in preventing their further development. Subsequent observations showed that there was no effect on the longevity of adults that developed from larvae which emerged from the treated drops.

Table 3.—Orchard experiments with benzene hexachloride, lead arsenate, and an ethylene dibromide soil treatment for control of the plum curculio on peaches.

TREATMENT (Quantities per 100 Gallons)	INFESTED DROPS (May 5–12)	INFESTED FRUIT AT HARVEST
	Per Cent	*Per Cent*
Benzene hexachloride (4.5% gamma): 2 lb. at petal fall, shuck-off, 2 weeks after shuck-off, and 4 weeks prior to harvest	53.2	34.4
4 lb. at petal fall, shuck-off, and 2 weeks after shuck-off, and lead arsenate 2 lb. 4 weeks prior to harvest	16.0	26.2
Lead arsenate 2 lb. at petal fall, shuck-off, and 4 weeks prior to harvest:	76.5	29.8
Plus benzene hexachloride (4.5% gamma) 4 lb. on drops under trees on May 9	71.8	25.8
Ethylene dibromide (62% emulsion), 300 ml. against larvae and 480 ml. against pupae[1]	82.2	52.4

[1] Applied to the soil at the rate of 1.78 gallons under each tree.

Treatment of Soil with Benzene Hexachloride.—Benzene hexachloride was also tested as a soil treatment against larvae and pupae in the soil. Where a dust was used it was worked into the soil; the sprays were applied to the soil surface. The results are given in table 4.

In each case the number of individuals reaching the adult stage and emerging from soil treated with benzene hexachloride was far too great for the treatment to be considered a practical one.

EFFECT OF THE NEW INSECTICIDES ON PEACH FRUIT, FOLIAGE, AND TREES.—No injury to fruit, foliage, wood, or buds resulted in these experiments from the use of benzene hexachloride, chlordan, chlorinated camphene, *Ryania*, or parathion. At dilutions of 0.67 to 2 quarts in 100 gallons single applications of hexaethyl tetraphosphate (with 3 ounces of sodium lauryl sulfate) caused moderately severe foliage injury and some defoliation. An application of the same material at 0.67 pint in 100 gallons on July 1 caused slight injury to the foliage. Lead arsenate caused about the usual amount of injury.

The flavor of the peaches was not affected by the benzene hexachloride schedules listed in table 3 or by an application of 4 pounds of the 4.5 per cent

Table 4.—Results of soil treatments with benzene hexachloride for curculio control.

TREATMENT (Pounds per 100 Gallons Unless Otherwise Indicated)	TIME OF APPLICATION	ADULTS EMERGING
		Per Cent
Dust, 1% gamma, 0.25 lb. per tree	1 day before larvae entered	71
Sprays (½ gal. per square yard of soil):		
4.5 % gamma 18 lb.	1 day before larvae entered	26[1]
3.79% gamma 6 lb.	6 days after larvae entered	66
12 lb.	After larvae pupated	33[1]
None	—	77

[1] Some beetles abnormal.

gamma-isomer material per 100 gallons on April 23, followed by 6 pounds of a 3.79 per cent gamma material on May 14, June 9, and July 1. In each case the last application of benzene hexachloride was applied no later than a month before harvest.

SUMMARY.—In cage tests, carried on at Fort Valley, Ga., in 1947, spray applications of parathion at rates of 0.5 to 2 pounds of 15 per cent wettable powder per 100 gallons of water, killed 100 per cent of plum curculio, *Conotrachelus nenuphar* (Hbst.), adults within 2 to 5 days. Cage tests indicated that chlorinated camphene, chlordan, and hexaethyl tetraphosphate are also promising insecticides for the control of plum curculio adults. In a single test tetraethyl pyrophosphate was insufficiently toxic to warrant further study. Benzene hexachloride, a material considered promising on the basis of previous tests, was only slightly more effective than lead arsenate. *Ryania* was relatively ineffective. Spray deposits of parathion were found to remain toxic to plum curculio adults for considerable periods after their application.

In comparable experiments conducted under commercial peach orchard conditions, benzene hexachloride gave no better control of the plum curculio than lead arsenate, which failed to give satisfactory control under the conditions prevailing in 1947. An application of benzene hexachloride on the drops, in combination with the regular schedule of lead arsenate sprays on the fruit, did not reduce the curculio infestation in the harvested fruit significantly. A schedule of three early benzene hexachloride sprays apparently reduced the number of early season peach drops.

Under 1947 conditions the benzene hexachloride schedules listed in table 3 or an application of 4 pounds of a 4.5 per cent gamma-isomer material per 100 gallons on April 23 followed by 6 pounds of a 3.79 per cent gamma material on May 14, June 9, and July 1, the last about 4 weeks before harvest had no effect on the flavor of the harvested peaches, and caused no injury to the fruit, foliage, buds, budwood, or other parts of the tree. Applications of chlordan, chlorinated camphene, *Ryania* and parathion likewise had no injurious effects. Hexaethyl tetraphosphate at a concentration as low as 0.67 pint in 100 gallons caused peach foliage injury. Benzene hexachloride applied on peach drops prevented the normal development of many plum curculio larvae and, at high dosages, had some adverse effect on the larvae that managed to emerge from the treated drops before there was sufficient penetration of the material to kill them. Benzene hexachloride was comparatively ineffective against plum curculio larvae or pupae in the soil.

LITERATURE CITED

Snapp, Oliver I. 1947. Benzene hexachloride for control of plum curculio on peaches. JOUR. ECON. ENT. 40(3): 382–5.

Relative Toxicity of the Isomers of Benzene Hexachloride to Several Insects[1]

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Slade (1945) and subsequent workers reported that benzene hexachloride exhibited its toxic properties as a contact poison, stomach poison, and as a fumigant. Although it seems apparent from the literature that the gamma isomer accounts for the high toxicity to insects, the other constituents may contribute some toxicity, the amount depending on the insect species. The majority of data in the literature are in terms of per cent mortality after a given exposure to a given concentration of technical benzene hexachloride based on gamma content. There is a paucity of information on the effects of the separate constituents of benzene hexachloride in terms of units of isomer applied per unit of body weight. It is necessary to have this information before a study of the mode of action of benzene hexachloride can be made.

With this in mind, this study was under taken to determine, on a quantitative basis, the relative toxicities of the separate constituents of technical benzene hexachloride to several insect species and stages.

CONTACT INSECTICIDE STUDIES.—Two species were used—the large milkweed bug, *Oncopeltus fasciatus* (Dall.), and the Mexican bean beetle, *Epilachna varivestis* Muls. The milkweed bugs were kept in a room maintained at a temperature of 78±2° F. All the insects were reared in glass jars on a diet of dried milkweed seeds and water. Only insects which had been adults at least four and not more than 7 days were treated. The Mexican bean beetles were reared under greenhouse conditions on French horticultural beans. Fourth instar larvae and one week old adults were treated.

The test methods used with both these species were so similar that they will be discussed together. Standard stock solutions of technical benzene heptachloride and each of the five known isomers of benzene hexachloride[4] were prepared with redistilled acetone. These solutions were diluted with redistilled acetone to the required concentrations and a measured amount was directly applied to the insect body by the use of a modification of the Nelson micropipette (Nelson, *et al.*, 1934).

The insects were inactivated by chilling them for a period of from one-half to two hours in a refrigerator at +24° F. The insects were weighed and then placed, in groups of five to ten, on a piece of white paper and arranged uniformly side by side. By means of the pipette, the insecticide solution was applied to the ventral part of the insect body, on the thorax between the legs and on the abdomen. The female milkweed bugs were larger and heavier than the male insects, therefore, in order that equivalent dosages could be applied and in order to investigate the possibility of differences in susceptibility, it was necessary to treat the sexes separately by varying the volume. No attempt was made to separate the sexes of either larval or adult Mexican bean beetles.

The treated insects and untreated checks were then placed in biological specimen dishes into which the proper food for the species was introduced and refreshed daily. These dishes were greased along the upper rims with vaseline so that the insects could not escape. In the case of the adult beetles, it was necessary to cover the dishes with cheesecloth in order to prevent their escape. The dishes were kept side by side in a room maintained at 78 ±2° F.

Readings were taken daily and the observations made six days after treatment were considered to be the most reliable and were used in the calculation of the dosage-mortality regression lines.

All dosages were calculated in terms of mg. of isomer per g. of insect body weight.

[1] These data are a portion of the results of research presented by the author in the dissertation for partial fulfillment of the requirements for the Ph.D. degree in Entomology at Cornell University.

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[3] The author wishes to acknowledge his indebtedness to Dr. L. B. Norton for his criticism, advice, and guidance.

[4] The alpha, beta, gamma, and delta isomers were separated from a commercial product and purified by the author and Dr. L. B. Norton. The epsilon isomer and additional supplies of the beta and delta isomers were supplied by the Dow Chemical Company. All isomers were recrystallized shortly before use, and had the following melting points: Alpha, 160.2–160.9° C.; Beta, 310.2–310.6° with sublimation; Gamma, 113.8–114.1°; Delta, 138.4–139.4°; Epsilon, 220.8–221.8°. The benzene heptachloride was a technical product supplied by California Spray Chemical Corporation, and had a melting range of 107.6–144.7°.

When the series of tests had been completed, the dosages were combined by grouping them in increments. The average dosage value, the total number of insects, and the number of dead were computed for each group. The observed mortality was corrected for natural mortality by Abbott's formula (Abbott 1925).

EXPERIMENTAL RESULTS AND DISCUSSION.—(a) Milkweed Bugs. Tables 1 and 2 present the toxicity data of the isomers of benzene hexachloride to the male and female milkweed bugs respectively. Although the alpha and delta isomers showed some toxic action, it was insignificant when compared with the gamma isomer at equivalent dosages. The beta and epsilon isomers showed no toxicity at the dosage levels used. There was no significant difference in resistance to the gamma isomer that could be attributed to the sex of the bug. The median lethal dose (M.L.D.) of the gamma isomer to the male was calculated by the method suggested by Finney (1947) as 0.00248 mg. per g. with limits of 0.00187 to 0.00327 mg. per g. for odds of 19 in 20. The M.L.D. of the gamma isomer for the female was 0.00289 mg. per g. with limits of 0.00256 to 0.00327 mg. per g.

It is of interest to compare the toxicity of the gamma isomer with other insecticides. Sherman (1943) studied the effects of nicotine, pyrethrins, and derris resins on the male and female milkweed bug using this measured drop technique. Table 3 gives the dosages of these materials necessary to produce 50 per cent mortality. By comparing these results with the gamma M.L.D., it would seem that the gamma isomer is approximately 2 times more toxic than the pyrethrins, 3 times more toxic than the derris resins, and 80 times more toxic than nicotine to this species.

(b) Mexican bean beetle. Tables 4 and 5 are compilations of the toxicity data of benzene heptachloride and the isomers of benzene hexachloride to the adults and fourth-instar larvae of the

Table 1.—Toxicity of the isomers of benzene hexachloride to the male large milkweed bug. Data taken six days after treatment. Dosage is in terms of mg. of toxicant per g. of body weight.

MATERIAL	DOSAGE MG. PER G.	NO. INSECTS TREATED	CORRECTED PER CENT MORTALITY
Alpha	9.23	20	32
	4.42	10	0
Beta	4.52	30	0
Gamma	0.0175	20	100
	0.0165	10	100
	0.00871	20	95
	0.00679	20	95
	0.00522	10	79
	0.00438	40	53
	0.00342	40	66
	0.00246	30	51
	0.00167	60	44
	0.000781	50	6
	0.000315	30	2
Delta	18.5	20	22
	9.23	20	11
	4.42	10	6
Acetone		112	5
Epsilon	6.33	50	0
Acetone		14	7

Table 2.—Toxicity of the isomers of benzene hexachloride to the female large milkweed bug. Data taken six days after treatment. Dosage is in terms of mg. of toxicant per g. of body weight.

MATERIAL	DOSAGE MG. PER G.	NO. INSECTS TREATED	CORRECTED PER CENT MORTALITY
Alpha	9.94	20	19
	4.31	10	14
Beta	4.64	30	7
Gamma	0.0175	30	100
	0.00837	30	93
	0.00596	20	95
	0.00452	40	65
	0.00350	40	62
	0.00255	30	39
	0.00173	60	27
	0.000809	50	3
	0.000329	30	0
Delta	19.9	20	25
	9.94	20	14
	4.31	10	0
Acetone		100	7
Epsilon	6.40	50	0
Acetone		33	12

Table 3.—The M.L.D. of nicotine, pyrethrins and derris resins for the male and female milkweed bug. Data taken 6 days after treatment.

Material	Male Mg. per g.	Female Mg. per g.
Nicotine	0.20	0.23
Pyrethrins	0.0045	0.0044
Derris resins (Total extractives)	0.0088	0.0072

Table 4.—Toxicity of benzene heptachloride and the isomers of benzene hexachloride to the adult Mexican bean beetle. Data taken six days after treatment. Dosage is in terms of mg. of toxicant per g. of body weight.

Material	Dosage Mg. per g.	No. Insects Treated	Corrected Per Cent Mortality
Alpha	29.7	20	0
	12.8	60	0
Beta	12.6	60	0
Gamma	0.620	20	100
	0.572	10	100
	0.243	20	100
	0.122	20	85
	0.0848	20	69
	0.0573	40	56
	0.0186	70	3
Delta	12.6	70	70
	5.96	40	90
	2.38	30	59
	1.28	40	25
	0.657	30	4
	0.297	20	7
	0.0572	10	0
Acetone		61	3
Epsilon	23.4	80	8
Benzene heptachloride	23.3	20	95
	17.8	50	96
	11.9	40	92
	5.71	50	69
	2.97	40	41
	1.43	50	25
	0.69	30	12
	0.33	10	0
Acetone		50	2

Mexican bean beetle. There was no significant difference in resistance between the larvae and the adults to either the gamma or delta isomers. The M.L.D. of the gamma isomer for the adult beetle was 0.0574 mg. per g. with limits of 0.0493 to 0.0668 mg. per g. for odds of 19 in 20 and for the immature stage was 0.0473 mg. per g. with limits of 0.0382 to 0.0586 mg. per g. The M.L.D. of the delta isomer for the adult was 3.12 mg. per g. with limits of 0.739 to 11.1 mg. per g. and for the larva was 1.83 mg. per g. with limits of 0.344 to 4.79 mg. per g. The adult beetle was found

Table 5.—Toxicity of benzene heptachloride and the isomers of benzene hexachloride to the fourth-instar larvae of the Mexican bean beetle. Dosage is in terms of mg. of toxicant per g. of body weight. Data taken 6 days after treatment.

Material	Dosage Mg. per g.	No. Insects Treated	Corrected Per Cent Mortality
Alpha	44.8	20	9
	17.6	50	0
Beta	17.6	40	0
Gamma	0.915	10	100
	0.604	20	100
	0.366	10	100
	0.277	40	92
	0.185	40	87
	0.0963	30	82
	0.0723	20	35
	0.0380	80	45
	0.0196	30	28
	0.00723	20	3
	0.000604	10	0
Delta	89.5	20	100
	44.8	20	100
	19.2	40	78
	13.1	30	64
	9.55	30	70
	3.69	30	68
	1.94	50	68
	0.989	40	46
	0.396	40	11
Acetone		99	7
Epsilon	24.1	30	22
	20.0	30	15
Benzene heptachloride	11.9	10	100
	6.13	10	100
	5.67	20	90
	4.51	20	85
	3.07	10	69
	2.54	50	59
	1.32	60	27
	0.75	20	13
	0.67	20	8
	0.58	10	8
	0.36	30	2
Acetone		44	2

to be more resistant than the larva to the benzene heptachloride. The M.L.D. of the benzene heptachloride for the adult was 3.13 mg. per g. with limits of 2.57 to 3.82 mg. per g. and for the larva was 2.05 mg. per g. with limits of 1.77 to 2.38 mg. per g.

A further comparison of these M.L.D. values shows that there was no significant difference between the toxicities of the delta isomer and the benzene heptachloride to both the adult and larval beetles since these values fall within each others fiducial limits. On the other hand, the gamma isomer was approximately fifty-four times more toxic to the adults and approximately forty times more toxic to the larvae than either the delta isomer or the benzene heptachloride. The alpha, beta, and epsilon isomers showed no significant toxicity at dosages approximately 100, 50, and 100 times the gamma M.L.D. respectively.

The dead adults among those treated with dosages of gamma and delta isomers corresponding to the high mortality levels (80–100 per cent) seemed to have died violently. They were on their backs and their legs and wings were outstretched. The dead adults among those which were treated with dosages corresponding to the lower mortalities did not exhibit those symptoms.

STOMACH INSECTICIDE STUDIES.—The Southern armyworm, *Prodenia eridania* (Cram.), which was reared under greenhouse conditions was used in this investigation. Egg masses were collected three times a week from an oviposition cage. The hatching larvae were kept in glass trays and were fed upon lettuce during their first two instars. Third-instar larvae were transferred to potted French horticultural beans. Fifth-instar larvae, 3–3.5 cm. long and weighing approximately 0.4 g., were utilized.

A modification of the inlay technique described by Bulger (1937) was employed. Bean leaf discs of uniform area were punched out using a #4 cork borer and stored in petri dishes containing moistened filter paper to prevent drying and shrinking. Pieces of leaf tissue were also prepared to act as bases for the treated discs. The stock solution of the isomer to be tested was diluted with redistilled acetone to the required concentration and by the use of a micropipette 0.011 ml. of solution was applied on the leaf disc. The acetone was allowed to evaporate, leaving a known weight of crystalline isomer on the disc. A thin layer of a soluble corn starch paste was applied on the base tissue. The sandwich was completed by carefully picking up the treated disc and placing it, treated surface down, on the base tissue. A holder for the treated leaf tissue was prepared by folding a piece of paper and clipping the base of the sandwich between the folds by means of an ordinary paper clip. Then by sticking a toothpick through the paper and standing the "sandwich holder" in a glass tray filled with sand, it was made ready for the insect.

Meanwhile, the fifth-instar larvae had been collected from the rearing benches in the greenhouse on the morning of the test. They were placed in large glass dishes containing absorbent paper bottoms (to absorb the excess moisture in the feces and keep the larvae clean) and kept without food for 4 hours. Each larva was weighed individually to the nearest hundredth of a gram and placed on the paper platform containing the treated tissue. A celluloid cylinder was placed around each "sandwich-holder" to prevent the escape of the insect. The insects were allowed to feed until they had completely devoured the treated tissue. This generally occurred within twenty minutes. Those insects which had not ingested all of the tissue within this period were discarded. The others were placed in small glass jars containing sand moistened to maintain a high humidity and a slice of potato for food.

The jars containing the individually treated insects were kept in a constant temperature room maintained at $78° \pm 2°$ F. and observed for a period of six days. Freshly sliced potatoes were introduced into the jars daily. The observations taken on the fourth day after treatment were utilized in the determination of the dosage-mortality curve. This observation was chosen because the majority of the insects had either died or pupated by this time. Those insects which were capable of pupation, or which moved upon gentle prodding with the tip of a pencil, were considered alive.

The modification utilized in this study is particularly applicable where small amounts of alcohol- or acetone-soluble materials are available for testing. Using a micropipette, the amount of material applied could be accurately measured,

standardized and reproduced. A further advantage of this modification is that the insect does not have to eat untreated tissue before it comes in contact with the treated disc and thus there is a greater chance of the leaf disc being completely ingested and the entire dose taken up by the insect.

EXPERIMENTAL RESULTS AND DISCUSSION.—Table 6 is a compilation of the toxicity data of the isomers of benzene hexachloride to the fifth-instar larvae of the Southern armyworm. As can be seen, only the gamma and delta isomers showed any appreciable toxicity.

Table 6.—Toxicity of the isomers of benzene hexachloride to the southern armyworm. Data taken four days after treatment. Dosage is in terms of mg. of toxicant per g. of body weight.

MATERIAL	DOSAGE MG. PER G.	NO. INSECTS TREATED	CORRECTED PER CENT MORTALITY
Alpha	2.14	26	0
Beta	1.26	29	0
Gamma	0.0624	9	100
	0.0540	12	100
	0.0448	38	100
	0.0360	45	89
	0.0245	65	55
	0.0148	55	20
Delta	2.79	8	100
	2.28	27	82
	1.72	21	76
	1.28	12	75
	0.630	16	13
	0.40	27	7
Epsilon	2.47	30	0

Bliss (1938) describes a method for the statistical treatment of individual mortality records such as was made in this investigation. The M.L.D. of the gamma isomer was calculated as 0.0219 mg. per g. with limits of 0.0201 to 0.0238 mg. per g. for odds of 19 in 20. The M.L.D. of the delta isomer was calculated as 1.05 mg. per g. with limits of 0.855 to 1.30 mg. per g. Thus, the gamma isomer is about 50 times more toxic to this species than is the delta isomer at the 50 per cent mortality level. The alpha, beta and epsilon isomers showed no toxicity at dosages approximately 100, 50 and 100 times the gamma M.L.D. respectively.

It is possible that the mechanisms of toxic action of the gamma and delta isomers are different. The symptoms of poisoning exhibited by the larvae affected by the two isomers were dissimilar. The clinical picture presented by the insects treated with the two materials is as follows:

THE EFFECT OF THE GAMMA ISOMER—Within 10 minutes at the higher dosages and within an hour at the lower dosages, the treated larvae began to swell at both extremities. At the same time a green fluid was ejected from both the oral and anal openings. The swelling, together with a muscular contraction of the body, caused the insect to resemble a weight lifter's "dumbbell." At the lower dosages, although the swelling and contraction were apparent, the symptoms were not as severe and recovery soon occurred.

The effect of the delta isomer—Symptoms were slower in developing then with the gamma isomer. Twenty-four hours after treatment, the affected insects were limp and inactive. They had lost body turgor and apparently the body muscles had lost their tonus. Within forty-eight hours many of the affected insects had recovered.

No ill-effects were noted from treatment with the alpha, beta, and epsilon isomers.

A preliminary investigation of the effect of gamma isomer when applied as a contact insecticide to this species was carried out. The median lethal dosage was calculated to be 0.21 mg. per g. From this it would seem that there is no significant difference in the toxicity of the gamma isomer which could be attributed to the method of application. The symptoms exhibited by the Southern armyworm when the gamma isomer was applied externally were the same as those occurring when it was applied as a stomach poison. This would seem to indicate that the penetration through the external body wall is as rapid and complete as through the gut wall.

FUMIGATION STUDIES.—The insects used in this study were: the red flour beetle, *Tribolium castaneum* (Hbst.), and the large milkweed bug, reared in the constant temperature room; the adult Mexican bean beetle reared under greenhouse conditions; and the sixth-instar larvae of the Fall webworm, *Hyphantria textor* Harris, obtained from two colonies infesting a mulberry tree.

The fumigation chambers consisted of one-quart fruit jars. Their volumes averaged approximately 970 ml. To act as the carrier for the toxicant, filter paper was cut so as to fit snugly the inside of the jar tops. Wire screen (16-mesh) was cut and fitted to the mouth of the jar to act as a barrier and prevent the insects from coming in direct contact with the isomers.

From the vapor pressure data for the isomers of benzene hexachloride at 20° and 40° C. determined by Smart and others (Slade, 1945), the amount necessary to saturate a volume of 970 ml. was calculated. The maximum amount needed was 2.8 mg. The vapor pressure data for the epsilon isomer and the technical benzene heptachloride were unobtainable from the literature but were assumed to be of the same order of magnitude as the others.

From 5.0 to 10.0 mg. of isomer was added to the filter papers from the stock solutions by means of a pipette. This was done to insure that the amount of material present in the fumigation jars would be sufficient to saturate the atmosphere and to allow for adsorption on the surfaces of the jars, on the insects, etc. While the acetone was evaporating, the insects were placed in the jars and the wire barrier put into position. As soon as no odor of acetone was detectable from the filter paper, the tops were put in place and the fumigation jars sealed.

The fumigation chambers were placed in constant temperature cabinets set at 59°, 68°, and 86° F. After varying periods of exposure, the insects were removed from the fumigation jars and were placed in biological specimen dishes to which food and water were added as required. They were kept in a room which was main tained at a temperature of 78±2° F. Observations were made daily for a period of four days.

Each replication consisted of ten insects per exposure for each of the species except the flour beetles. One hundred flour beetles were used for each replication.

EXPERIMENTAL RESULTS AND DISCUSSION.—Tables 7 to 10 present the results of the fumigation tests using the technical benzene heptachloride and the isomers of benzene hexachloride against the various insect species. The per cent observed mortality was corrected for natural mortality by Abbott's formula.

It was apparent that the gamma isomer had a definite toxic effect as a fumigant. The only other isomer showing appreciable toxicity was alpha and then only against the milkweed bug. The beta, delta and epsilon isomers and the benzene heptachloride showed little or no toxicity against the insect species used.

The observations made four days after exposing the insects to the vapors of the gamma isomer were used in plotting the regression lines. The data were plotted as log-hours exposure vs. probit mortality.

Table 7.—The toxicity of the isomers of benzene hexachloride as fumigants to the adult milkweed bug. Date taken four days after exposure. Amount of isomer applied: 5.0 to 10.0 mg.

Material	Temp. °F.	Time Exposure Hours	Number Insects Treated	Corrected Per Cent Mortality
Alpha	59	24	30	13
	68	24	30	33
	86	24	70	72
Beta	59	24	20	10
	68	24	20	0
	86	24	50	14
Gamma	59	1	30	30
		2	30	23
		3	30	70
		4	40	90
		8	30	100
		24	40	100
	68	1	30	47
		2	30	93
		3	30	100
		4	40	100
		8	30	100
		24	40	100
	86	1	30	80
		2	30	100
		3	30	100
		4	40	100
		8	30	100
		24	40	100
Delta	59	24	20	0
	68	24	20	0
	86	24	50	10
Check (untreated)	59	24	25	0
	68	24	20	5
	86	24	40	5
Epsilon	59	24	30	0
	88	24	30	0
	86	24	30	0
Benzene heptachloride	59	24	30	0
	68	24	30	0
	86	24	30	30

Table 8.—The toxicity of the isomers of benzene hexachloride as fumigants to the adult red flour beetle. Data taken 4 days after exposure. Amount of isomer applied: 5.0 and 7.5 mg.

Material	Temp. °F.	Time Exposure Hours	Number Insects Treated	Corrected Per Cent Mortality
Alpha	59	24	100	0.0
	68	24	100	0.0
	86	24	200	1.0
Beta	59	24	100	0.0
	68	24	100	0.0
	86	24	200	0.0
Gamma	59	4	300	0.0
		8	300	1.3
		24	300	80.7
	68	4	300	22.7
		8	300	56.7
		24	300	92.7
	86	4	300	58.7
		8	300	75.3
		24	300	99.7
Delta	59	24	100	0.0
	68	24	100	1.0
	86	24	200	1.0
Check (untreated)	59	24	100	0.0
	68	24	100	0.0
	86	24	200	0.0

Table 9.—The toxicity of the isomers of benzene hexachloride as fumigants to the sixth-instar larvae of the Fall webworm. Data taken 4 days after exposure. Amount of isomer applied: 5.0 to 7.5 mg.

Material	Temp. °F.	Time Exposure Hours	Number Insects Treated	Corrected Per Cent Mortality
Alpha	59	24	10	0
	68	24	10	0
	86	24	10	0
Beta	59	24	10	0
	68	24	10	0
	86	24	10	0
Gamma	59	4	20	30
		8	20	35
		24	20	55
	68	4	20	35
		8	20	50
		24	20	70
	86	4	20	10
		8	20	60
		24	20	100
Delta	59	24	10	0
	68	24	10	20
	86	24	10	0
Check (untreated)	59	24	10	0
	68	24	10	0
	86	24	10	0

From these regression lines, the exposure time necessary to produce 50 per cent mortality among the insects studied, were calculated (table 11). It appears that the relative order of decreasing toxicity to the gamma isomer was: the large milkweed bug, the red flour beetle, the Fall webworm, and the Mexican bean beetle.

Over the range of temperatures studied, the toxicity of the gamma isomer increased with an increase in temperature. This was to be expected for several reasons. The vapor pressure of the toxicant increased with a rise in temperature, giving a higher concentration. Although sufficient toxicant to saturate the confined atmosphere was added to the fumigation chambers, the speed of volatility of the isomers . . . . unknown. Therefore it is a matter of conjecture whether the atmosphere was actually saturated with the isomer. The speed of volatility of a solid and the rate of diffusion of a gas increases with a rise in temperature. Therefore, although saturation might not have been reached during the period of exposure, more isomer would have been vaporized and become available to the insect at the higher temperatures.

In addition to the purely physical effect upon the toxicant already discussed, the higher temperatures increase the respiration of the insects causing most fumigants to be more effective.

SUMMARY.—The relative toxicities of the five known isomers of benzene hexachloride as contact insecticides, stomach insecticides, and fumigants were investigated. The insect species used were: the red flour beetle, *Tribolium castaneum* (Hbst.); the male and female adult large milkweed bug, *Oncopeltus fasciatus* (Dallas); the fourth-instar larval and adult Mexican bean beetle, *Epilachna varivestis* Muls.; the fifth-instar larval Southern armyworm, *Prodenia eridania* (Cram.); and the sixth-instar larval Fall webworm, *Hyphantria textor* Harris. The toxicity of benzene heptachloride was also tested against several of these species.

Two species were used in determining

Table 10.—The toxicity of the isomers of benzene hexachloride as fumigants to the adult Mexican bean beetle. Data taken 4 days after exposure. Amount of isomer applied: 5.0 to 10.0 mg.

Material	Temp. °F.	Time Exposure Hours	Number Insects Treated	Corrected Per Cent Mortality
Alpha	59	24	10	0
	68	24	10	0
	86	24	50	0
Beta	59	24	10	0
	68	24	10	0
	86	24	50	10
Gamma	59	4	40	10
		8	40	3
		24	50	10
	68	4	40	3
		8	40	3
		24	50	44
	86	4	40	5
		8	40	32
		24	50	96
Delta	59	24	10	0
	68	24	10	0
	86	24	50	6
Check (untreated)	59	24	10	0
	68	24	10	0
	86	24	40	5
Epsilon	59	24	30	0
	68	24	30	0
	86	24	30	0
Benzene heptachloride	59	24	30	0
	68	24	30	0
	86	24	30	0

Table 11.—Time of exposure to gamma isomer necessary to produce 50 per cent mortality 4 days after treatment.

Insect	Exposure Temperature, °F.	Exposure Time Hours
Milkweed Bug	59	2.1
	68	1.0
	86	< 1.0
Tribolium	59	17.5
	68	7.1
	86	3.4
Mexican Bean Beetle	59	>24.0
	68	26.4
	86	9.8
Fall Webworm	59	17.2
	68	8.3
	86	7.2

the toxicity of the isomers as contact insecticides: the large milkweed bug and the Mexican bean beetle. There was no significant difference in the toxicity of the gamma isomer to either sex of the milkweed bug. The alpha, beta, delta, and epsilon isomers showed negligible toxicity to either the male or female insects at approximately 4000, 2000, 8000, and 2500 times the gamma M.L.D. respectively.

There was no significant difference in resistance between the larval and adult Mexican bean beetles to either the gamma or the delta isomer. The adult beetle was found to be more resistant than the larva to the benzene heptachloride. The relative order of potency of the toxic materials against both the adults and the larvae were: the gamma isomer, the delta isomer, and the benzene heptachloride. The alpha, beta, and epsilon isomers were comparatively non-toxic to this species.

The effects of the isomers as stomach poisons on the Southern armyworm were determined. The gamma isomer was approximately 50 times more toxic than the delta isomer. The alpha, beta, and epsilon isomers showed no toxicity at dosages approximately 100, 50, and 100 times the gamma M.L.D. respectively. A preliminary test was made of the effect of the gamma isomer as a contact insecticide on this species. It would seem that there was no significant difference in the effect of the gamma isomer that could be attributed to either method of application.

The fumigation effects of the isomers and the benzene heptachloride at three temperature levels were studied. It was apparent that the gamma isomer had a toxic effect on all the species tested. It appeared that the relative order of susceptibility to the fumigation effect of the gamma isomer was: the large milkweed bug, the red flour beetle, the Fall webworm, and the Mexican bean beetle. The only other isomer showing appreciable toxicity was alpha and then only against the large milkweed bug. The beta, delta, and epsilon isomers showed little or no toxicity.

The different symptoms exhibited by the Southern armyworm when affected by the gamma and delta isomers suggested the possibility of different mechanisms of toxic action.

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Benzene Hexachloride and Other Insecticides to Control Cotton Insects in Arizona

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The cotton-insect problems in Arizona are very complex, each cotton-growing area presenting somewhat different problems. The insects involved include several plant bugs and stink bugs, the bollworm, the beet armyworm, thrips, aphids, cotton leaf perforators, several beetles, and the cotton leafworm, their relative importance varying from section to section and from year to year. The most serious problem is the control of the plant bugs—namely, several species of *Lygus*, *Creontiades femoralis* Van D., *Adelphocoris superbus* (Uhler), *Psallus seriatus* (Reut.)—and the stink bugs—namely, *Euschistus impictiventris* Stål, *Chlorochroa sayi* Stål, and *Thyanta custator* (F.).

Over a period of years profitable gains in yields of seed cotton from the control of these insects have been made by the proper use of sulfur-arsenical mixtures (mainly 7.5 per cent of paris green in sulfur), but the results have been variable. The results of experiments with DDT in 1944 and 1945 were so outstanding in controlling most cotton pests and increasing yields that it was generally used by the growers in 1946. A more effective and faster acting insecticide, however, is desirable for stink bugs. Preliminary tests conducted in 1945 showed benzene hexachloride to be effective against stink bugs, and this material was included in a number of experiments in 1946. The hemipterous-insect populations were much lower during 1946 than for several years, but even so some noteworthy results were obtained. The results obtained with benzene hexachloride in comparison with DDT and other insecticides at various locations in Arizona are reported in this paper.

AIRPLANE DUSTING EXPERIMENTS.—Two fields located at Buckeye comprising 114 acres of short-staple cotton, separate by an irrigation ditch and a field road, were divided into 6 plots each, varying in size from 6.5 to 15 acres. Two plots were treated with DDT, two with benzene hexachloride, and two check plots in each field were left untreated. Population records were made at weekly intervals throughout the growing season by the sweep-net method. The dusting was done by Airplane on August 1, 9, and 19, and September 5 and 25 at, the rate of 20 pounds per acre. The results from the two fields, designated as the north field and the south field, are given in table 1. The insect populations were much lower than usual in this area. The untreated plots produced more than 2 bales per acre, but profitable gains were secured from all treatments, especially with the DDT mixtures.

A 35-acre field of short-staple cotton at Litchfield Park was divided into an 18-acre plot for dusting with 5 per cent of DDT in sulfur and a 17-acre plot for dusting with benzene hexachloride. Two applications were made of each insecticide, the

[1] The authors were assisted in the field by John M. Breazeale and Louis W. Sheets.

Table 1.—Comparative effectiveness of DDT and benzene hexachloride against injurious cotton insects in airplane-dusted experimental fields, Buckeye, Arizona, 1946.

Treatment	Number of Injurious Insects per 100 Strokes		Average Yield of Seed Cotton	Average Increase in Yield Over Check[1]
	Seasonal Average	Peak	Pounds per Acre	
	North Field			
DDT 5% in sulfur	4	12	3620	422
Check	6	10	3253	—
Benzene hexachloride, gamma 1%	4	12	3553	355
DDT 10% in sulfur	4	16	3882	685
Check	8	15	3144	—
Benzene hexachloride, gamma 2.5%	5	14	3648	450
	South Field			
DDT 5% in sulfur	3	8	3954	410
Check	6	12	3759	—
Benzene hexachloride, gamma 1%	4	10	4031	487
DDT 10% in sulfur	3	12	3791	247
Check	7	12	3329	—
Benzene hexachloride, gamma 2.5%	4	12	3936	392

[1] Average of two checks.

first on August 3 and the second on August 16. The dosage was 20 pounds of dust per acre. Benzene hexachloride dust containing 1 per cent of the gamma isomer was used in the first application and a product containing 2 per cent of the gamma isomer in the second application. The insect populations were low in both plots except just prior to August 12, when an influx of stink bugs brought the mixed populations to a peak of 58 per 100 net strokes in the DDT plot and 26 in the benzene hexachloride plot. The populations after August 16 dropped to 6 in the DDT plot and 2 in the benzene hexachloride plot and then, continued at a low level for the remainder of the season. The DDT-treated plot yielded 2776 pounds of seed cotton per acre, and the benzene hexachloride plot 2311 pounds.

A 74-acre field of short-staple cotton at Marana was divided into a 26-acre plot for dusting with 5 per cent of DDT in sulfur, a 26-acre plot for dusting with 50 per cent of sulfur and enough benzene hexachloride to give 2 per cent of the gamma isomer and a 22-acre plot which was left untreated for a check. The plots were dusted on August 6, 13, and 21 at the rate of 20 pounds per acre. The populations of injurious Hemiptera were extremely low in this field throughout the season, reaching a peak of 7 per 100 strokes in the check on July 31. *Lygus* bugs and the cotton fleahopper predominated. The final yields showed an average of 2001 pounds of seed cotton per acre for the DDT plot, 2253 for the benzene hexachloride plot, and 1943 for the untreated plot. The cotton in this field was picked from November 13 to December 18. The lint turnout was over 40 per cent when picking was begun and dropped to a little less than 35 per cent because of drying out before the picking was completed. The check plot was picked first, then the benzene hexachloride plot, and the DDT plot last.

A number of fields in southern Arizona were treated with a dust containing 20 per cent of sabadilla at the rate of 15 to 20 pounds per acre for stink bug control. In most fields good control was secured, but in a few fields sabadilla was a complete failure. This material is rather expensive, and the supply is uncertain.

AIRPLANE SPRAYING EXPERIMENT.—A 9-acre field of short-staple cotton at Buckeye was treated by airplane on August 14 with a concentrated benzene hexachloride spray. The spray was applied at the rate of 3.5 gallons per acre, which was a little over 4 ounces of the gamma isomer. Sweeping records made just prior to the application showed 12 stink bugs and 4 *Lygus* bugs per 100 sweeps. Counts made 22 hours after treatment showed 3 stink bugs per 100 sweeps, or a reduction of 80 per cent, and no *Lygus* bugs. Dead stink bugs could easily be found on the ground. This demonstration was so out-

Table 2.—Comparative effectiveness of insecticides tested against injurious cotton insects in hand dusting experiments at Marana, Arizona, 1946.

Treatment	Number of Injurious Insects per 100 Strokes		Average Yield of Seed Cotton	Average Increase in Yield Over Check
	Seasonal Average	Peak	Pounds per Acre	
DDT 5% in sulfur	2	7	3586	398
DT 10% in sulfur	2	9	3382	194
Benzene hexachloride, gamma 2%	2	7	3225	37
Ryania powder 25% in pyrophyllite	1	10	3461	273
Check	3	10	3188	—

standing that several hundred acres of commercial cotton were treated with this spray, and all counts showed about the same reduction in insect populations.

HAND DUSTING EXPERIMENTS.—A 6-by-6 latin square composed of 0.025-acre plots of short-staple cotton located on the experimental farm of the University of Arizona at Mesa was used in one hand dusting experiment. Applications of DDT, paris green, and benzene hexachloride were made with rotary hand dusters at the approximate rate of 20 pounds per acre on July 9 and 23 and August 6 and 13. The increase in yield was greatest in the plot treated with 10 per cent of DDT in sulfur and the least in that dusted with paris green.

A 5-by-5 latin square composed of 0.038-acre plots of short-staple cotton located on a cotton grower's property at Marana was used in another experiment. DDT, benzene hexachloride, and *Ryania* powder were applied on July 26 and August 1, 15, and 22 with rotary hand dusters at the approximate rate of 20 pounds per acre on each date. All insecticides tested had excellent dusting qualities with the exception of 10 per cent of DDT in sulfur, which was very lumpy and gritty and almost impossible to apply efficiently. Table 2 shows the results.

RESULTS WITH SULFUR-DDT DUSTS.—The beet armyworm, *Laphygma exigua* (Hbn.), causes some damage to seedling cotton in Arizona every year but usually disappears about the time the cotton begins to form squares. The first generation is usually highly parasitized but this was not so in 1946. Three distinct broods or generations were found in some cotton-growing areas. The injury caused by the second- and third-generation worms on the squares and blossoms was similar to that caused by bollworms. This insect was brought under complete control with one application of 5 per cent of DDT in sulfur at the rate of 15 to 20 pounds per acre. Several thousand acres of cotton in Arizona were dusted for the control of this insect, as well as large acreages in California.

Approximately 10,000 acres of cotton were dusted in Pima and Santa Cruz Counties primarily for control of the bollworm, *Heliothis armigera* (Hbn.), with 5 per cent of DDT in sulfur at the rate of 20 to 25 pounds per acre. Without exception this mixture gave excellent control of the bollworm. Inspections after dust applications revealed many large dead worms in blooms and on the ground.

These experiments verify results obtained in previous experiments that 5 per cent of DDT in sulfur is the most satisfactory insecticide for general use against cotton insects in Arizona.

Soybean Insects in Minnesota with Special Reference to Sampling Techniques[1]

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It is generally recognized that there is no insect pest of economic importance found exclusively on soybeans. Reports of damage all refer to sporadic outbreaks of some of the general plant feeders, and most of the insects reported as having damaged soybeans are species which are uncommon or not found in Minnesota. Morse & Carter (1939) listed the insects they considered the more likely potential threats for soybeans grown in the northern part of the country. Essentially, this list is identical to one of the alfalfa insects of this area; including grasshoppers, the gray blister beetle, several leafhoppers, several flea beetles, the cucumber beetle, the green clover worm, the army worm and other leaf feeding species. Balduf (1923) made a comprehensive 3-year study of the insects found on soybeans and the surrounding vegetation in Ohio. The majority of the 209 different species taken occurred only in small numbers and would ordinarily be found in any weed and grass environment. He concluded that some of the species could be dangerous to the crop, but that *Empoasca fabae* (Harris) and related sucking insects had the most detrimental effect upon the plant growth.

METHODS.—During the summer of 1946, a study was made to find what insects might be included in a normal population on soybeans in Minnesota. Three types of sampling were used in this study; cylinder, sweep, and unit leaves. Sampling cylinders were constructed of sheet celluloid fastened to a wire frame. Celluloid base plates with light wooden frames were laid out beneath the plants the day before the cylinders were placed over the plants in sampling. This procedure greatly facilitated gathering up the insects in a sample by eliminating the need for separating them from the soil beneath the plants. It was assumed that active forms would have reassumed their normal positions on the plants before the sample was taken. The killing agent used was potassium cyanide with 10 per cent sulphuric acid added for quick evolution of the gas. A somewhat similar collection method was described and used by Romney (1945).

Sweep samples were taken in units of 15 sweeps per sample on various soybean fields about the state and in the units of three sweeps per sample in conjunction with cylinder samples for a comparison of the two methods.

Leaf unit samples were used in determining the number of nymphs of *Empoasca fabae* in order to give a comparison between cylinder and sweep sampling methods.

This study was made at the University Experiment Station Farm, St. Paul, Minnesota and on various farms throughout the state. Nine randomized plots at University Farm were planted with the varieties Wisconsin Manchu 606, Ottawa Mandarin, and Bansei.

PHENOLOGICAL FIELD OBSERVATIONS.—The seasonal tabulation shown in Table 1 was drawn up in order to provide a correlation between the date, the stage of growth of the plants, and the important events which took place.

INSECT SPECIES ON SOYBEANS.—From the 298 sweep and cylinder collections made, 84 specific identifications were made and 28 other groups were identified to family. Only 39 of the identified species appeared in more than 10 different collections. Although species which do not occur more than 10 times out of a possible 298 collections can scarcely be of much significance in a plant community, collection data of one season is inadequate for establishing all the significant insects. The study made by Balduf (1923) in Ohio over a 3-year period may serve as a basis for some comparison. He found that the families Cicadellidae, Fulgoridae, Miridae, and Chrysomelidae included 39 per cent of all species taken. In this study, the four families listed included 29 per cent. Balduf found also that these four families plus the Acrididae, Tettigoniidae, and Noctuidae made up 95 per cent of the total individuals collected. In this study, the four families Cicadellidae, Chrysomelidae,

[1] Acknowledgement is made of the suggestions and advice given by Dr. A. C. Hodson in the organization and analysis of the data.

Miridae, and Noctuidae included 80 per cent of the total individuals with 60 per cent being the nymphs and adults of *Empoasca fabae*. Generally speaking, the insect population of soybean plants in Minnesota is comparable to that found in Ohio so far as families are concerned.

Among the leaf feeding insects, there are a few which might be considered potential pests because of their regular occurrence. One of the first to appear in the spring was *Diabrotica duodecimpunctata* (Fab.). It was present all during the growing season and evidence of feeding was constantly present. In a sample of 120 leaves, only 11.28 out of total of 1364.50 square inches of leaf area or less than 0.1 per cent was consumed by it and the other leaf eating forms present. Grasshoppers were only occasional feeders but under certain conditions could cause great damage. The green clover worm, *Plathypena scabra* (Fab.), was kept under control quite effectively by *Voria ruralis* (Fallon) and *Apanteles flaviconchae* (Riley). However, considerable damage was done by these larvae on some fields in 1944.

Empoasca fabae must be considered the major pest by sheer force of numbers. The damage from these insects is usually not evident, causing only a loss in vitality to the plant. The control of leafhoppers on potatoes by means of DDT has shown such pronounced increases in yield, that we are just beginning to realize how much of a drain these insects can be on a plant.

Table 1.—Phenological field observations.

DATE	LEAVES PRESENT	REMARKS
27 May		Seeds planted. Late, cold spring.
7 June	Cotyledons up.	Spotty germination, apparently due to the weather.
11 June	3	Wind, rain, and hail storm shredded up the first leaves considerably.
17 June	6	No insect damage visible on the plants.
20 June	9	*Dibrotica duodecimpunctata* (Fab.) found eating large irregular holes in upper leaves. Damage more apparent on the variety Wisconsin Manchu 606.
26 June	12	Cylinder samples yielded no insects. Bacterial leaf spot appeared in the plot.
28 June	12	First instars of *Empoasca fabae* appeared on the lower leaves of the plants. These leaves appeared to have lost a good share of their original pubescence.
1 July	18	Population sampling begun on a regular basis. Larvae of *Plathypena scabra* appeared on the upper leaves of the plants.
9 July	24	Blossoming begun on the lower portion of the plant. Grasshopper nymphs were first observed feeding in the plots.
15 July	36	The central portion of the plant was in bloom and the pods had set on the lower portion. An average of 1 in 5 leaves showed some signs of feeding damage by the leaf eating insects.
24 July	54	Lower leaves on the plants were beginning to yellow, apparently due to shading, but new leaves were still being added. Upper portion of the plant in bloom.
5 Aug.	48	Lower yellowed leaves dropping off. Pods set on the entire plant.
14 Aug.	33	Leaves continuing to yellow with the lower ones continually dropping off.
22 Aug.	24	General yellowing of the foliage on the variety Ottawa mandarin. The last of July and all of August had been extremely dry and part of the yellowing may have been due to this condition.
31 Aug.	18	Most of the leaves had dropped on the Ottawa Mandarin. Yellowing and dropping of the foliage more pronounced on Wisc. Manchu.
5 Sept.	3	Majority of the leaves had fallen on both varieties and those still hanging on were yellowed.

POPULATION COMPARISON ON TWO VARIETIES.—Since most of the soybeans grown in this state are members of the Mandarin and Manchu varieties, a comparison of the populations found on representatives of these two groups was made. The varieties used were Ottawa Mandarin and Wisconsin Manchu 606. Table 2 is a graphic illustration of this comparison.

This graph shows that the population on each type is almost identical. The proportionate abundance of any particular species is such that the only variation present might be considered to occur normally between plants of the same variety. The variation therefore could not be attributable to a particular perference by any insect for either plant type.

Table 2.—Total insect population comparison of cylinder samples on two varieties of soybeans.

SCIENTIFIC NAME	I[1]	II[2]
Empoasca fabae (Harris)	663	516
Empoasca fabae nymph	647	641
Triphleps insidiosa (Say)	69	43
Exitianus obscurinervus nymph	51	46
Macrosteles divisus (Uhl.)	35	40
Triphleps insidiosa nymph	31	27
Exitianus obscurinervus (Stal.)	28	22
Lygus pratensis nymph	17	10
Lygus pratensis Linn.	13	8
Plathypena scabra (F.) larva	12	2
Chloropisca glabra (Meig.)	12	17
Anthomyiidae	12	16
Diabrotica duodecimpunctata (Fab.)	10	7
Chrysopa spp. larvae	8	3
Sciomyzidae	7	4
Agromyzidae	7	
Macrosiphum dirhodum (Walk.)	6	5
Nabis ferus nymph	6	9
Aeolothrips fasciatus Linn.	5	2
Tychius picirostris (Fab.)	5	1
Cecidomyiidae	5	3
Tenthredinidae	5	1
Nabis ferus Linn.	4	1
Melanopthalma gibbosa Herbst	4	1
Braconidae	4	1
Chalcididae	4	4
Liburnia campestris nymph	3	4
Psylla spp.	3	3
Macrosiphum pisi (Kalt.)	3	5
Stethorus punctum (Lec.)	3	
Madiza setulosa Mal.	3	2
Opomyzidae	3	2
Collembola	2	
Macrosteles divisus nymph	2	3
Deltocephalus sonorus Ball	2	3
Liburnia campestris (Van D.)	2	
Aphis cephalanthi (Thomas)	2	4
Amphorophora cosmopolitana Mas.	2	
Adelphocoris lineolatus nymph	2	5
Adelphocoris rapidus (Say)	2	6
Epitrix cucumeris Harris	2	3
Scatopsidae	2	
Psilidae	2	4
Madiza nigripalpus Mal.	2	1
Ichneumonidae	2	
Corrodentia	1	1
Sericothrips variabilis (Beach)	1	
Macrosiphum gei Koch	1	3
Orthotylus flavosparsus (Sahl.)	1	
Strongylocoris breviatus (Knight)	1	
Halticus bracteatus (Say)	1	
Phelister subrotundus Say	1	
Ploeosoma punctata Lec.	1	
Hippodamia convergens Guer.	1	3
Hippodamia parenthesis Say	1	
Ceratomegilla fuscilabris (Muls.)	1	
Lathridius liratus Lec.	1	
Systena blanda (Melsh.)	1	1
Diacrisia virginica Fab. larva	1	2
Chironomidae	1	
Mycetophilidae	1	1
Simuliidae	1	
Pipinculidae	1	
Hippelates plebejus Loew	1	1
Formica spp.	1	
Apis mellifera Linn.	1	
Ceresa bubalis Fab.		4
Nysius ericae Schilling		3
Scaphytopius acutus (Say)		2
Macrosiphum granarium (Kirby)		2
Anthicus cervinus Laf.		2
Sarcophagidae		2
Chrysopa oculata Say		1
Chirothrips manicatus Hal.		1
Campylenchia latipes (Say)		1
Aceratogallia uhleri (Van D.)		1
Typhocyba gillettei (Van D.)		1
Macrosiphum ambrosiae (Thomas)		1
Periphyllus populicola (Thomas)		1
Adelphocoris lineolatus (Goeze)		1
Piesma cinerea Say		1
Cymus angustatus Stal.		1
Disonycha triangularis Say		1
Longitarsus turbatus Horn		1
Dolichopodidae		1
Empididae		1
Vespidae		1

[1] I = Wisconsin 606.
[2] II = Ottawa Mandarin.

POPULATION DIFFERENCES DUE TO CULTURAL PRACTICES.—On a cultural basis, the fields used in this study could be divided into two principal groups; weedy, close drilled fields and clean cultivated, spaced fields. In general, the weedy fields had a larger and more varied population. This difference was most marked in the case of the flea beetles, *Systena taeniata* Say and *S. frontalis* Fab.; in the Miridae, *Lygus pratensis* L., *Orthotylus flavosparsus* (Sahl.), *Strongylocoris breviatus* (Knight); and in the case of the families Chermidae, Sciomyzidae, and Chloropidae.

There was one marked exception to this general trend in the case of *Empoasca fabae* (Harris). These leafhoppers occurred more than five times as abundantly in the clean cultivated fields as in the weedy ones. Table 1 shows little difference in numbers on the two varieties of the general groups grown in the state. The more abundant foliage and generally increased vigor in the spaced fields may be a partial explanation. The more direct exposure to the sun and higher temperature in the microclimate may have some effect. Carter (1930) showed that temperature has the greatest effect on the development of this leafhopper while the relative humidity is the primary factor in survival.

COMPARISON OF SWEEP AND CYLINDER

SAMPLES.—As might be expected, both qualitative and quantitative differences were found in this comparison. DeLong (1938) attributed this difference in part to the greater number of variables involved in the sweep sampling method. This method greatly overestimated the abundance of some of the species and underestimated others. In order to provide a basis for a comparison of the two methods, sweep samples were taken in conjunction with cylinder samples on the experimental plots. Three sweeps taken with the standard American net were used as a unit sample. The ratios of occurrence given in table 2 represents the fraction, mean number per sweep sample over mean number per cylinder sample. This table is set up with the species listed in order of the ratio magnitude on the 15th of August. Only those species appearing consistently in both methods were used in setting up this table. These figures illustrate the fact that sweep sampling gives an inaccurate picture of the true population present. *Empoasca fabae* (Har.), adults and nymphs, which were by far the most abundant, have a very small ratio of occurrence in the sweep samples. Beall (1935) has discussed how the magnitude of this fraction may be affected in several ways.

A comparison of the ratios for any species for the two dates shows that the ratio of occurrence is continually undergoing changes. Those species with the highest ratio on August 15 have a very low ratio on August 22. Part of this change is believed due to a shift in the species comprising the population. Because such changes are to be found, it becomes impossible to set up a standard ratio of occurrence for any particular species which will apply throughout a season. Various authors have attempted to do this by setting up a certain number of sweeps as equivalent to a cylinder sample of a given area.

Table 3.—Comparison of collections by sweep and cylinder methods.

NAME	AV. NUMBER—AUG. 15			AV. NUMBER—AUG. 22		
	Sweep	Cylinder	Ratio	Sweep	Cylinder	Ratio
Ceresa bubalis (Fab.)	.25	.04	6.25	.00	.00	.00
Chrysopa oculata (Say)	.17	.04	4.25	.04	.00	.04
Aeolothrips fasciatus L.	.13	.08	1.62	.00	.17	.00
Macrosteles divisus (Uhl.)	.25	.25	1.00	.48	.04	12.00
Macrosiphum dirhodum (Walk.)	.08	.08	1.00	.00	.12	.00
Hippodamia parenthesis (Say)	.04	.04	1.00	.00	.00	.00
Ceratomegilla fuscilabris (Muls.)	.04	.04	1.00	.00	.00	.00
Triphleps insidiosa (Say)	.50	.62	.81	.31	1.04	.29
Psylla sp.	.08	.12	.66	.00	.00	.00
Diabrotica duodecimpunctata (Fab.)	.08	.12	.66	.33	.00	.33
Nabis ferus L. nymph	.17	.37	.45	.12	.04	3.00
Existanius obscurinervus (Stal.)	.08	.31	.19	.04	.08	.50
Empoasca fabae (Har.)	1.33	10.07	.12	2.41	5.29	.45
Lygus pratensis L.	.08	.00	.08	.12	.04	3.00
Nabis ferus L.	.04	.00	.04	.08	.04	2.00
Empoasca fabae (Har.) nymph	.41	14.50	.03	.33	5.79	.06
Adelphocoris rapidus (Say)	.00	.00	.00	.12	.04	3.00

Other workers have used as a basis for comparison the total numbers of insects collected by each method. Such a comparison shows that on August 15 the sweep collections numbered 121 while the cylinder collection was 592, the ratio being .20; on August 22, the sweep count was 150 and the cylinder count 354, ratio .42. The average for the two is thus—Sweep count 135, Cylinder count 473, ratio .28.

On the basis of the average number collected on the two dates by these two methods, the ratio of occurrence would be .28. Thus a three sweep sample on the average would yield .28 times the number of insects collected in a single cylinder sample. Accordingly, a twelve-sweep sample might be expected to approximate most closely a cylinder sample on the basis of the total number collected. Yet, a comparison of the ratios for these two weeks shows that they are not constant. Considering the totals collected by each

method, one would conclude that the larger the population present, the smaller the proportion of the insects caught by sweeping. This would be increasingly true in proportion to the size of the plant sampled. Since soybeans attain a height of 30 to 36 in., only the upper portion of the plant is included in a sweep sample. Here then, is one explanation for the differences in ratios for the two dates. By August 22, a number of the lower leaves on the plants had yellowed and dropped off. Thus, the population on the plant was concentrated more on the upper remaining leaves and the size of the population which could be supported was reduced.

Romney (1945) concluded from his studies on the beet leafhopper caught on peppergrass that a natural variation in leafhopper numbers occurred from plant to plant in cylinder samples which could not be considered sampling error. This variation was found to be as great as that between sweep net samples when the size of area samples was the same. He felt therefore that a sweep net will give a reliable sample from the standpoint of variation, if the effects of temperature and wind velocity are accounted for. The plant which he sampled in these experiments never exceeded a height of 15 inches. With this size plant, a sweep sample includes the entire plant. The ratios of occurrence show that as the leaf surface available on the plant is decreased by one-third, the ratio was doubled. This would indicate that the reliability of sweep sampling is closely related to the proportion of the plant included in that sample.

COMPARISON OF NYMPHAL SAMPLING METHODS.—In a population study, the nymphal population is sometimes disregarded and sometimes included as a part of the total count for a species. Since the nymphal and larval stages of some species are of greater importance than the adults in the economy of the plants, separate records should be kept of these forms.

A comparison of sweep and cylinder samples shows that sweep samples underestimated the immature stages of all the species with the exception of the larvae of the green clover worm, *Plathypena scabra* (Fab.). This difference is attributable to the position of the larvae on the plants. They were all found on the upper, well expanded leaves and were easily collected in the sweep samples. Other immature forms were spread out over the entire plant and thus were less likely to be in a position to be adequately represented in a sweep sample.

In the case of the nymphs of *Empoasca fabae* (Har.), a unit leaf sampling method was also used. Counts show that there was a considerable discrepancy in the average number of nymphs per plant in a comparison of concurrent leaf and cylinder samples. Field inspection showed that in the first three weeks of sampling, the nymphs were confined to the lower leaves of the plants. This concentration appeared due to a preference by the insects for the older leaves with less dense pubescence. During these first 3 weeks, therefore, the leaf samples taken were biased to the extent that the whole sample was taken from the lower portion of the plant, whereas the cylinder samples were taken including all the leaves on the plant. After the third week, the nymphs could be found over all the leaves and the leaf samples were then taken at random from the entire plant. It is shown that leaf sampling grossly overestimated the nymphal population per plant for the first three weeks, but that the general population trend of the cylinder samples was followed for the remainder of the season.

There are two possible explanations for the discrepancies in the latter part of the season. One source of error may be that in the cylinder samples all the nymphs may not have been dislodged from the plant in the collecting process. A second source of error may be the nomadic behavior of the nymphs after the peak population had passed. Continual migrations took place from one stem to another on the plants. Cylinder samples included these migratory forms but the leaf sampling method missed them. This may account for the drop of the leaf sampling estimation below that of the cylinder samples.

SUMMARY AND CONCLUSIONS.—1. A study was made of the insect population found on soybean plants in Minnesota. Sampling was done by means of sweep samples, unit leaf samples, and cylinder samples. For the cylinder samples, special celluloid base plates were constructed to facilitate collection of the specimens and closed celluloid cylinders were constructed for ease of handling.

2. Only 39 species were found to occur

Table 4.—Summary of nymphal data on *Empoasca fabae* (Harris).

Date	Trifoliate Leaf Samples			Cylinder Samples
	Av. Nymphs per Leaf	Av. Leaves per Plant	Av. Nymphs per Plant	Av. Nymphs per Plant
5 July	.42	6	2.52	.03
10 July	.52	24	12.48	1.30
16 July	.51	36	18.36	3.63
24 July	.18	54	9.72	4.92
31 July	.22	51	11.22	6.57
10 Aug.	.31	48	14.88	14.91
15 Aug.	.31	33	10.22	18.35
22 Aug.	.05	21	1.05	5.91
29 Aug.	.01	18	.18	1.53
5 Sept.	.00	6	.00	.71

more than 10 times out of a possible 298 collections. The most important species would therefore most likely be included in the 39 both from the standpoint of significant damage to the plants and from the standpoint of possible disease transmission. Eighty per cent of the total individuals collected belonged to the families Cicadellidae, Chrysomelidae, Miridae, and Noctuidae. The predominant species collected was *Empoasca fabae* (Har.) with the nymphs and adults of it making up 60 per cent of the total population.

3. There was no significant difference in the insect populations found on the two main varietal types, Mandarin and Manchu, grown in the state.

4. Comparison of sweep and cylinder samples taken from the same site shows that the sweep samples are unreliable for the estimation of numbers of any particular species present. The species which were the most abundant, were the most underestimated. In the comparison of total numbers collected by each method, the sweep samples were found to have an average ratio of .28 to a cylinder sample. On this basis, a sweep sample of 12 sweeps might be expected to approximate the number collected in a cylinder sample. The reliability of the sweep samples, however, is correlated with the size of the plant and the vertical spread of the leaf surface. A one-third reduction in the amount of leaf surface available was found to double the ratio of occurrence.

5. A comparison of the nymphal sampling methods on *Empoasca fabae* (Har.) shows that unit leaf sampling may give an inaccurate picture of the population. Discrepancies are largely attributable to position changes on the part of the nymphs.

6. A comparison of samples taken from fields around the state which were grown under clean cultivation and under weedy conditions shows that the latter contained more insects, considered both qualitatively and quantitatively. The one exception found was in the case of *Empoasca fabae* (Har.) which occurred over five times as abundantly in the clean cultivated fields.

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LOCAL COMMITTEE ON ARRANGEMENTS FOR 1948 MEETING

Presidents Knight and Rohwer have joined in appointing the following Committee on local arrangements for the annual meetings of the Entomological Society of America and the American Association of Economic Entomologists to be held at the Hotel New Yorker, New York, N. Y., December 13–16, 1948.

George C. Becker — C. H. Curran
Harry Haynes — R. S. Filmer
Charles L. Smith, *Chairman*

Oil Spray Investigations in British Columbia[1]

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Petroleum oil first came into common use in British Columbia orchards in 1923 when it was applied as a dormant treatment at 8 per cent concentration for control of fruit tree leaf roller, *Archips argyrospila* (Wlkr.). Presumably the emulsifier was a soap, because in one district hard water caused the spray mixture to break badly, resulting in extensive injury; thereafter casein-ammonia was employed in emulsification. It is not known when attention was first paid locally to oil specifications but in the thirties the recommendations of the Western Cooperative Oil Spray Project for dormant oil (100–110 Visc. and over 55 per cent U.R.)[2] were in effect. Little thought was given to summer oil specifications since, prior to 1939, comparatively little oil of this type was used; but it was understood that, as advised by the Spray Project, a summer oil should be of 53 to 75 Visc. and over 85 per cent U.R.

Beginning in 1939 the British Columbia Fruit Branch,[3] the Dominion Division of Chemistry[4] and the Dominion Division of Entomology undertook an investigation of various petroleum fractions and blends with the object of setting up a reliable basis for selection of spray oils for local conditions. This work has led to the general use of 200–220 Visc. dormant oil and so-called "low sulphonation" summer oil. Since it has also indicated that much of our knowledge about spray oils is too casual, the investigation is being continued with increased emphasis on fundamentals. The present paper is a brief progress account of results of the field work in which all members of the Dominion Entomological Laboratory at Summerland, B. C., have taken part. Reports on laboratory research, including detailed analyses of oils will be made at the discretion of the Division of Chemistry.

EUROPEAN RED MITE.—One of the uses of dormant oil in British Columbia is for control of European red mite. *Paratetranychus pilosus* (C. & F.). Table 1 indicates that the winter eggs of this form are more readily killed by 220 Visc. oil than by 110 Visc. oil, both from California crude and characterized by a V.I. presumed to be less than 50. In this case, no V.I. determinations were made but later determinations on samples from the same source were of that order.

Table 1.—Effect of dormant oils on European red mite.

Year	Sprayed	Examined	Gal. per 100	Mites per 100 Leaves: Check	110 Visc.	220 Visc.
1939	March	May	1.5	6800	3500	2100
			3.0		1200	700
1940	March	May	0.75	4230	2820	2390
			1.5		1610	1310
1941	March	May	1.5	142	133	130
			3.0		59	24

APPLE MEALYBUG.—Unlike a number of other insects which may be controlled by dormant oil, the apple mealybug, *Phenacoccus aceris* Sig., is unusually susceptible to the lighter cuts of petroleum, even stove oil being fairly effective. Table 2 illustrates this point. The two more viscous oils were those referred to in table 1.

Table 2.—Effect of dormant oils on apple mealybug.

Year	Sprayed	Examined	Gal. per 100	Check	Egg Masses per 25 Terminals: 32 Visc.	110 Visc.	220 Visc.
1939	March	June	2	353	—	70	159
			4		—	29	47
1940	April	June	2	387	295	200	362
			4		74	36	81
1941	March	May	2	667	115	57	—
			4		29	12	

SAN JOSÉ SCALE.— Experiments with different types of dormant oil for control of San José *Aspidiotus perniciosus* Comst. scale were not undertaken until 1945. They indicate (Table 3) that, in agreement with Pearce *et al.* (1941), an oil of high V.I. is more effective than one of low V.I., and furthermore, that an oil of 220 Visc. is more effective than one of 110 Visc.

[1] Contribution No. 2533 Division of Entomology, Science Service, Department of Agriculture, Ottawa, Ont.

[2] Visc. (viscosity) refers to Seconds Saybolt Universal at 100°F. unless otherwise stated; U.R. refers to A.O.A.C. unsulphonated residue and V.I. to viscosity index.

[3] Represented by Ben Hoy, Provincial District Horticulturist, Kelowna and R. P. Murray, Provincial District Horticulturist, Penticton.

[4] Represented by J. M. McArthur and M. P. D. Trumpour.

Table 3.—Effect of dormant oils on San José scale.

Year	Gal. per 100	Per Cent Infested Fruit		
		106 Visc 94 V.I.	108 Visc 11 V.I.	204 Visc 3 V.I.
1945	4	2.3	21.6	6.5
1946	4	3	60	34

Oil deposits averaged from eight replicates and calculated as milligrams per square centimeter, were:

	1945	*1946*
106 Vis. 94 V.I.	0.67	0.61
108 Vis. 11 V.I.	0.59	0.53
204 Vis. 3 V.I.	0.59	0.66

The evidently greater effectiveness of high V.I. oil seems to have been due not to greater deposit but to some factor or factors inherent in the oil.

PHYTOTOXICITY OF DORMANT OILS.—Beginning in 1942, for 3 years, during the dormant or delayed-dormant period, various oils were applied to Anjou pear trees to determine their tendencies to cause plant injury. Depending on the year, the oils were used at both 10 and 5 per cent or at 6 per cent concentration as casein-ammonia emulsions. Table 4 lists two of the specifications of each oil and the effects of the oils on pear trees.

Considering the trials of the 3 years together, 38 Visc. oil caused injury comparable to 105 Visc. oil and was somewhat more injurious than 214 Visc. oil. Much the most injurious was 110 Visc. oil of high V.I. This was unexpected, in view of the findings of Pearce *et al.* (1942) who concluded "There is an indication—that some of the more efficient (*i.e.*, high V.I.) oils are likewise safer for use on fruit trees."

During 1945, 1946 and 1947 three of these oils were applied to apple trees. Their effects in respect of delayed bud development and bud injury were somewhat similar to those described for pear except that, in comparing the western light and heavy dormant oils, differences were more pronounced. Each year the mid-continent high V.I. light dormant oil was distinctly the most injurious of the three. The oil deposit determinations mentioned in the previous section on San José Scale control indicate that the obvious differences in degree of phytotoxicity were not due to variation in amount of oil deposit.

In yet another experiment nine 200–211 Visc. dormant oils varying in such respects as V.I., flash point, gravity and pour point were compared with a 105 Visc. oil of low V.I. and a 109 Visc. oil of high V.I. Although the last oil did not show the

Table 4.—Injury to Anjou pear trees from dormant oils.

Year	Source	Visc.	V.I.	Conc.	Effect on Trees
1942	Calif.	38	101	5%	No buds killed. No arrested bud development.
				10%	7% buds killed. Considerable arrested bud development.
	Calif.	105	41	5%	5% buds killed.
				10%	50% buds killed.
	Calif.	214	−13	5%	No buds killed. Some arrested bud development.
				10%	10% buds killed.
1943	Calif.	38	101	5%	No buds killed. No arrested bud development.
				10%	10% buds killed. Delayed blossom opening. Primary leaves atrophied.
	Calif.	105	41	5%	2–3% buds killed. Some arrested bud development. No commercial damage.
	Calif.			10%	10% buds killed. Leaf bud development much delayed. No delayed blossom opening.
	Calif.	214	−13	5%	2–3% buds killed. No commercial damage.
				10%	10% buds killed. Leaf bud development delayed. No delayed blossom opening.
	Mid-continent[1]	110	100	5%	Same as 10% (double conc.) 105 Visc. Western oil.
				10%	60% buds killed. Blossom injury severe—about 80% crop loss.
1944	Calif.	38	101	6%	Few buds killed but pronounced delay in development.
	Calif.	101	?	6%	Few buds killed. Evident delay in bud development but less than with 38 Visc. oil. No commercial damage.
	Calif.	216	?	6%	Similar to 101 Visc. oil.
	Mid-Continent[1]	110	100	6%	Considerable bud killing (25%?). Very pronounced delay in bud development.

[1] "Forum 40." Imperial Oil Co., Sarnia, Ont.

highest oil deposit it was, once again, decidedly the most injurious. Other characteristics being similar, it therefore appears that a low V.I. oil of 220 Visc. is somewhat less prone to cause injury than a low V.I. oil of 110 Visc. and considerably less likely to do so than a high V.I. oil of 110 Visc.

Perhaps the relationship of oil viscosity to temperature change might be given greater attention when spray oil specifications are erected. It is true that the viscosity index indicates that relationship as a numerical value, but it hardly suggests, for example, the following variations in viscosity of dormant oils at different temperatures:

V.I.	*Visc. 100° F.*	*Visc. 50° F.*
100	110	436
41	105	460
−13	214	1600

Since dormant oils are applied when temperatures are closer to 50 than 100° F., information on viscosity at the lower temperature seems a logical requirement.

EFFECTS OF OILS ON TRUNKS OF APPLE TREES.—As further evidence for the view that heavy Western dormant oil is less injurious to fruit trees than western oils of lower viscosity, an experiment in connection with codling moth tree trunk sprays begun in 1942 and completed in 1947 may be cited.[5] Ten different petroleum fractions or blends were annually applied undiluted to main limbs and trunks of Jonathan and McIntosh apple trees; three healthy, mature trees comprised a plot.

As will be seen from table 5 the most injurious oil proved to be the lighter fractions. Stove oil and 38 Visc. distillate were particularly destructive to the cambium although light summer oil caused serious damage after two applications. Less injurious were medium summer oils; still less so was light Western dormant oil. Least injurious was heavy western dormant oil. As in the trials with diluted dormant sprays, mid-continent (high V.I.) light dormant oil was more injurious than a Western oil of similar viscosity but of low V.I. The unsulphonated residue of an oil seemed to have no bearing on its tendency to cause cambium injury.

Table 5.—Effects of various oils on trunks of apple trees.

TYPE OF OIL	VISC. 100° F.	V.I.	U.R.	NUMBER OF ANNUAL APPLICATIONS TO KILL 3 TREES
Stove oil	32	220?	86%	3—(2 trees dead after 2 applications)
Distillate (Diesel)	38	101?	73%	3—(2 trees dead after 2 applications)
Light summer	55	56	89%	3
Med. summer	71	69	90%	4—(2 trees dead after 3 applications)
Med. summer (low U.R.)	73	22	68%	4—(1 tree dead after 3 applications)
Light Western dormant	105	40	63%	5—(2 trees dead after 4 applications)
Light Mid-continent dormant	110	100	69%	4
Heavy Western dormant	251	−58	56%	6—(none completely killed after 5 applications)
Check (9 trees)	—	—	—	No injury.

SUMMER OILS.—As with dormant oils, so the specifications of summer oils have been changed to meet British Columbia conditions. For 5 years several types of petroleum fractions and blends were compared as summer sprays in codling moth experimental plots. The standard of comparison was medium oil of 77 Visc. and 94 per cent U.R. Four to five applications a year eventually demonstrated that oils of 65 to 79 Visc. and 75 per cent U.R. were not visibly more injurious to apple foliage or fruit than the "high sulphonation" oil and had comparable effectiveness. Since, in this province, the former oils cost less than half as much as the "high sulphonation" products they have entirely superseded them.

In the course of the work, a black residual fuel oil (bunker oil) of over 1200 Visc. and, according to standard A.O.A.C. procedure, 4 per cent U.R. (probably inaccurate for this type of oil) was applied at 0.5 per cent concentration in five cover sprays to three varieties of apple. Its gummy residue caused the trees to ap-

[5] Carried on jointly with the Dominion Experimental Station, Summerland, B.C. and the Dominion Laboratory of Plant Pathology, Summerland, B.C.

pear abnormally dark in colour but did not give rise to any serious foliage or fruit injury. Indeed, of all the oils under trial at the time, residual oil was the only one which, when applied a week following sulphur treatment, caused no foliage drop. This exceedingly viscous oil was subsequently cut with stove oil to give blends of 50 Visc. and 100 Visc. The lighter oil was not sufficiently effective as an ovicide, while the heavier one left a tenacious brown deposit on the fruit; accordingly they were not proposed for grower use. These experiments suggest that in common with dormant oil specifications, those for summer oil require critical study.

DISCUSSION.—The foregoing résumé suggests the need for basic research in spray oils. In some instances, what were evidently but assumptions seem gradually with the passing years, to have taken the role of facts. More chemical and physical data are required and they should be carefully compared with insecticidal effectiveness and phytotoxicty. The significance of distillation range even yet is not clear, nor is that of viscosity, viscosity index, gravity, unsulphonated residue, flash point, pour point and perhaps aniline point and other characteristics still to be enumerated. Various series of working samples, each series with but a single widely varying characteristic, would be most helpful. The excellent researches of Pearce, Chapman and Avens in the State of New York show what is possible in this connection. Chemist, phytopathologist, horticulturist and entomologist must pool their efforts if the problem is to be handled adequately.

SUMMARY.—1. An investigation of spray oils was begun in British Columbia in 1939 and is still in progress. It has led to the recommendation and general use of a high viscosity dormant oil heretofore not believed applicable in the West. It has likewise resulted in the general use of summer oil of low unsulphonated residue.

2. Dormant oil of 200 to 220 S.S.U. viscosity at 100° F. was more effective against San José scale and European red mite than oil of 100 to 110 S.S.U. viscosity and caused less injury to apple and pear; it was less effective against apple mealybug.

3. Dormant oil of high viscosity index (presumably from mid-continent crude) was more effective against San José scale than California oil of similar viscosity at 100° F. but of low viscosity index; it was, however, more injurious to fruit trees. Differences in performance of these oils are not attributed to variations in amount of oil deposit.

4. Applied undiluted to the trunks of apple trees over a period of 6 years, fuel oils and light summer oils proved considerably more injurious than light dormant oil; in turn, light dormant oil of 100 to 110 S.S.U. viscosity at 100° F. was more injurious than heavy dormant oil of 200 to 220 S.S.U. viscosity. Here again, oil of high viscosity index caused more damage than oil of low viscosity index. The unsulphonated residue of an oil seemed to have no bearing on its tendency to cause cambium injury.

5. When used at 0.5 per cent concentration in five applications, summer oil of low unsulphonated residue (75 per cent) was not visibly more injurious to apple fruits or foliage than oil of high unsulphonated residue (94 per cent).

6. Residual fuel oil (bunker oil), of 1200 S.S.U. viscosity, 100° F. at 0.5 per cent concentration as a summer spray caused no more visible injury to apple than summer oil of 77 S.S.U. viscosity and 94 per cent unsulphonated residue. Unlike the latter oil it did not cause defoliation when applied shortly after a sulphur spray.

7. There is need for more fundamental research on spray oils.

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Host Selection by the Pine Engraver

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An important problem in forest entomology is the determination of factors which influence tree selection by insects. This is especially true in the study of those insects which spend part of their lifetime in the subcortical region of host trees. Attacks by many of these inner-bark feeders are frequently predisposed by a decreasing resistance of the trees caused primarily by other unfavorable intrinsic or extrinsic factors. One of these factors which has been associated with several bark beetle epidemics is deficient rainfall (Felt (1914), Blackman (1924), Craighead (1925a), St. George (1929), and Eaton (1941). Craighead (1925b) also recognized that depredations of the western pine beetle, *Dendroctonus brevicomis* Lec., were connected with host decadence.

These findings, which emphasize the importance of host vigor, suggested the need for a study of the way bark beetles select the weakened trees most suitable for attack; therefore, the work reported here was undertaken. The bark beetle used for this study was the pine engraver, *Ips pini* (Say). All the trees and logs were jack pine, *Pinus banksiana* Lamb. The field work was carried out in north-central Minnesota during the summer months of 1940 and 1941.

Ips pini is typical of the bark beetles in that the adults bore into the inner bark where they carry on their reproductive functions. The males make the initial attack by boring into a tree or log where they excavate a small nuptial chamber in the inner bark. Soon each male is joined by one or more females which excavate tunnels radiating out from the central nuptial chamber. Along the sides of these galleries the females cut niches into which the eggs are deposited. After the larvae are hatched, they tunnel away from the egg galleries and feed on the fresh, undiscolored parts of the inner bark. When the larvae have transformed into adults, the young beetles continue to bore and feed in the inner bark for a short time before they emerge. They then fly away and attack other trees or logs. A more detailed account of the biology of this species is given by Clemens (1916).

CONCENTRATION OF ATTACK.—Many subcortical feeding insects frequently concentrate their attacks on a few trees rather than infest lightly a large number. Such a response is especially favorable to the attacking insects whenever the resistance of the host has to be overcome before the attack can succeed. The writer has observed this gregarious characteristic by many species of bark beetles including *Dendroctonus brevicomis* Lec., *D. frontalis* Zimm., *D. monticolae* Hopk., and *Ips pini* (Say), and by the flatheaded borers *Melanophila californica* Van. D. and *Agrilus anxius* Gory, and roundheaded borers of the genus *Monochamus*.

When *Ips* infestations were studied it was noted that the initial entrances were made after the logs had been exposed for more than a week. The number of attacks then increased rapidly. The long preinfestation period probably resulted because the logs were exposed in a rather open area where other breeding material was absent. This condition necessitated an emigration of the attacking beetles from an adjacent jack pine stand where they were reared.

The rapid rate of increase of infestation following initial attacks suggested that the attacking beetles themselves were conducted to determine whether this idea was correct. The tests consisted of caging freshly attacked logs in areas removed from the site of initial attacks and placing suitable uninfested logs outside the the cages but adjacent to them. Shortly after the infested logs had been caged—frequently within an hour—beetles began to congregate on the screen, attempting to reach the logs inside. Soon they would move to the adjacent uninfested logs and attack them. In 78 such tests, 77 per cent of the logs outside the cages became infested on the first day, 9 per cent on the second day, 10 per cent on the third day, and the remaining 4 per cent on the fourth day. When the first attack was delayed longer than 1 day the weather was usually rainy and

[1] The writer is very grateful to F. C. Craighead and H. J. MacAloney, both of the Bureau of Entomology and Plant Quarantine, and A. C. Hodson, of the University of Minnesota, for helping to make this study possible.

cool. Of the 25 checks, 7 became infested in an average of 14 days, whereas the other 18 did not become infested through the 1 to 3 week exposure periods. Beetles caged alone and an extract made from beetles were both unattractive.

These observations indicate that the attraction of beetles is more dependent on the activity of pioneer attacking beetles than on the attractiveness of the host material itself. As would be expected from the previous observations, the strength of attraction was found to be dependent on the number of fresh attacks. Based on 16 observations, where the new attacks at the beginning of the test averaged 0, 4, 26, and 86, the beetle entrances made during the following 24-hour period averaged 0, 2, 60, and 132, respectively. The correlation coefficient was +0.94, which indicates that the relationship is highly significant.

This attraction, however, did not continue very long. Exposure of logs with attacks 4, 7, 14, and 28 days old resulted in no new entrances being made during the following 24-hour period. Similar logs with attacks only 1-day old averaged 13 new entrances during the next 24-hours. In another observation newly attacked logs were caged and the number of beetles attracted to the cage were counted daily. During the first 3 days there averaged 10 to 29 beetles per observation, the largest number being observed on the second day. On the fourth day and thereafter there was a marked decrease, so that from the sixth to tenth days only 1 or 2 beetles were observed per observation. The beetles were not removed from the cage when the observations were made.

From replicated observations it was found that when newly emerged males were caged alone with logs the resulting attacks continued to be attractive to other beetles for 2 to 9 days. When females alone were caged with logs, they bored in and made short galleries, but such attacks were not attractive to other beetles. In the 3 replicates 4, 13, and 17 females attacked. For one test in which the attacking males were supplied with an abundance of females the attraction immediately ceased. Beetles when caged alone without logs or when mashed were also unattractive to other beetles. These results indicate that only the males when working alone in the bark attract other beetles—both males and females.

This same method of concentrating attacks apparently is characteristic of some of the more aggressive species of bark beetles. Patterson & Edmonston, as reported by Craighead (1925b), were able to induce a general attack on individual trees by caging newly emerged adults of the western pine beetle on a portion of the trunk. Later Caird (1935) used the same method to get the southern pine beetle to attack shortleaf pine.

That *Ips* beetles were drawn to the particular spot where the attraction originated and not to the general area was demonstrated by producing an attraction, in the manner already described, around which uninfested logs were placed at distances of 10, 20, 30, and 40 feet. During the first few days many beetles crawled about on the outside of the cage; yet no attacks occurred on any of the exposed logs.

Attractiveness of the infested logs was not dependent on the odor of the extruded boring dust, for dust was continually being pushed out of the logs for 15 or more days after the logs had lost their attractiveness.

Person (1931) suggested that the odors resulting from fermentation in the inner bark may attract the western pine beetle. He reported—"But after a few attacks are made a second, stronger attraction is started by the yeast introduced by the attacking beetles, finding the inner bark a favorable medium for its growth. This secondary attraction is probably strong enough to attract beetles for a considerable distance. . ." In the present study, however, these odors did not attract *Ips pini* from a distance. The amount of fermentation should have increased as the attacks grew older, because the microorganisms would have been inoculated into more and more of the inner bark tissues as the females extended their galleries. The observations indicate, however, that the attraction decreased as the insect attack became older.

In one experiment yeasts isolated from bark beetle galleries were inoculated in the inner bark of two series of 9 logs each. These logs were then exposed to beetles in the field. Two jars of mashed inner bark were also inoculated with the yeast and then placed adjacent to uninfested logs in the field. The jars of mash soon

produced a rich, resinous, yeasty, acid odor, but no odor could be detected close to the inoculated logs. None of the treated logs and none of the logs placed beside the jars of mash were attacked sooner than the checks.

The pleasant odor which could be detected close to freshly made entrance holes suggests that attraction may be due to an odoriferous substance emitted by the males.

Whatever may be the nature of the attractant, it undoubtedly is responsible for concentrating the beetles in the most suitable host material. It may also explain the group killing of trees which is characteristic of attacks by the more aggressive species of *Dendroctonus*. When a large population of beetles is produced, large numbers of adults are attracted to the few scattered trees that have been located and are being attacked by the pioneer beetles. As the infestation develops, the attraction becomes stronger and the influx of beetles greater. Very soon all the bark space in the trees originally attacked is filled, and the excess beetles attack adjacent trees. Even though the beetles may not find these trees as desirable as those initially attacked, they are able to overcome quickly the resistance of more vigorous trees by attacking simultaneously in large numbers.

INITIAL ATTRACTION TO HOST TREES.—A few observations on how the first attacking beetles select the most desirable trees appear pertinent. Person (1931) theorizes with reference to the western pine beetle that—"This initial attraction, [due to volatile odors of respiratory fermentation] particularly in trees only slightly subnormal, is probably so weak as to be detected only by beetles in the immediate vicinity of the tree." The present work also showed the initial beetle attraction to uninfested suitable host material to be weak.

When uninfested logs were exposed alone, it took the beetles 11 days or more to find and attack them. During the same time beetles were attacking logs from the same trees used for other experiments in the same general area. Obviously these logs did not produce a strong attractant.

The beetles could not readily detect suitable host material even after they had attacked. One series of logs was cut and stored in a building for a year before being exposed to beetle attack. Even though the inner bark of these logs was brown at the time of exposure, 7 of the 10 logs were subsequently attacked (4 by two entrances each, 2 by 10 each, and 1 by 36. None of the attacks progressed very far, although some of the egg galleries had been extended to a distance of 10 cm. from the nuptial chamber. No larvae survived. Attacks also occurred in water-soaked logs in which brood survival was very poor.

It was easy to induce *Ips pini* to attempt an attack even on vigorous trees by attracting the beetles to the trees with newly infested logs. Some of the attracted beetles attempted to attack the trees, but after they reached the inner bark they all stopped boring and vacated the tunnels, None was trapped in the resin. Nineteen entrances were attempted in the two trees tested.

These observations suggest that suitable breeding material by itself did not produce an attractant strong enough to draw *Ips pini* beetles from a distance. Instead, they were induced to enter the log or were repelled only after they were close to it. After a suitable tree was encountered, the attacking beetles produced the attractant and thereby drew other beetles to the tree. From this time on in the same manner more and more beetles became concentrated in the particular tree or log being attacked.

The reason some beetles went to uninfested trees rather than to trees already attacked is not known. Probably they searched for new material only when they were outside the effective range of an attraction center, or the threshold of the receptors to the attractant was so high in some beetles that they were stimulated only when they were extremely close to an attraction center. It was observed, however, that practically all of the beetles attracted by the fresh attacks were light brown, which indicated that they had emerged recently.

EFFECT OF INNER-BARK MOISTURE CONTENT ON HOST SELECTION.—Inept as some beetles were in detecting suitable host material, probably most beetles were successful if suitable trees and logs were available. An attempt was made, therefore, to determine the factors affecting the beetles in the selection of suitable host material. Because of its great impor-

tance in determining the vigor of plants, moisture was the most obvious factor, and it was carefully studied.

The first observation on the effect of moisture was made in July 1940 on some pole-sized trees broken by an ice storm 3 months previously. The 10- to 15-foot snags which lacked living branches were attacked by *Ips pini*, whereas snags having only a few short living branches (even only one 3-foot branch) were generally avoided by the beetles. These two types of snags were damaged by the storm to almost the same degree; yet the beetles were able to differentiate between them. Moisture determinations made of the inner bark in these trees, however, showed that there was a considerable difference between the two classes. The inner-bark of the snags attacked was almost 100 per cent wetter than that of snags which the beetles passed by. These data are summarized in table 1.

Table 1.—Moisture content of the inner bark of damaged and undamaged trees. 1940.

TREE CONDITION	MOISTURE CONTENT	TREES OBSERVED
	Per cent	*Number*
Undamaged	215±3	27
Topped, 1 to 5 live branches remaining	215±5	18
Topped, no live branches remaining	302±6	49

Each determination was made from a sample of about 80 square centimeters of bark. The inner succulent tissue was separated from the dry outer bark and immediately placed in the drying container. The outer bark was discarded. Temperatures were kept at 100° to 110° C. to dry the samples to constant weight. All moisture percentages are based on the dry weights of the samples.

It was found that the moisture content decreased somewhat as the height increased; therefore, the data in table 1 are from samples collected at a trunk height of about 5 feet. The moisture content of undamaged trees averaged 217 per cent at a trunk height of 3 feet, 211 at 7 feet, 205 at 11 feet, 212 at 15 feet, 201 at 19 feet, and 186 at 23 feet. Five trees were sampled at each of the heights listed. The correlation coefficient is −0.47, which is highly significant. A similar decrease was also noted in 2 completely storm-topped snags. In these the inner-bark moisture content averaged 281 per cent at a trunk height of 2 feet, 273 at 6 feet, and 262 at 10 feet.

A difference in inner-bark moisture content was noted also in branchless snags of red pine, *Pinus resinosa* Ait., as compared to that in unbroken trees. The averages were 259±15 and 208±14 per cent for 3 snags and 3 unbroken trees.

After the observations already described, suggesting that *Ips* attack was associated with moisture content, other experiments were conducted to learn more about this relationship. Log sections 1 foot long were taken from the same tree to eliminate differences due to variations in different trees. The water content of the inner bark of these logs was then varied by wetting some of the logs and by drying others. To speed the drying, the logs were split and then air dried; to increase the water content, the logs were placed upright in a shallow pan of water. After various periods, the treatments were discontinued and the cut ends of the logs were paraffined. These logs from the same tree, but with different inner-bark moisture contents, were then exposed in a location where beetles were known to be present.

In the first test the logs with various inner-bark moisture contents were exposed together but were randomized. After a period of 3 weeks the 10 drier logs with inner bark moisture contents of 132 to 300 per cent averaged 2.4 beetle entrances per log, whereas for the 13 wetter logs with 311 to 448 per cent inner bark moisture there were 4.3 entrances per log.

In a second test the treatments were separated from each other by about 10 feet. Twelve logs were used for each treatment. The counts of beetle entrances were made after 1 month of exposure, but moisture determinations were not made. Preference for the dried and soaked logs is shown in the following tabulation:

	Number of Entrances per Log
Dried	8.5
Untreated	0.2
Soaked 5 hours	5.3
Soaked 12 hours	2.6

Further observations on this relation-

ship were made by using a more rapid technique which consisted in placing a soaked (or dried) log together with an untreated log next to a cage containing freshly attacked logs. The logs for each observation were taken from adjacent parts of the same tree bole and were placed so that they were in contact neither with each other nor with the cage. Ten logs were used for each treatment. The results of these tests support those of the previous tests in that the soaked logs were initially more attractive than the untreated logs. There were also more entrances in the dried logs than in the untreated; however, the difference was not significant. The number of entrances per log after 18 hours were as follows:

	Soaked	Dried
Treated	5.2	1.7
Untreated	2.4	0.6
Difference required for significance at odds of 19 to 1	2.5	1.3

Significance of the relationship of inner-bark moisture content to increased attractiveness for *Ips pini* may be that changes in moisture content are associated with the dying process. In a series of 11 4-foot logs cut from vigorous trees the inner-bark moisture content decreased from 205 ± 5 to 182 ± 6 during a 4-week period, even though the log ends had been waxed and the logs kept inside. They were then infested with *Ips*, and 4 weeks later, when the brood was maturing, the inner-bark moisture content had increased to 312 ± 13 per cent. This increase in moisture content was not entirely associated with the infestation, for in a similar but uninfested series of 9 logs the inner cortex also became more hydrated during a 10-week storage period. The average percentages and standard errors were 210 ± 14 and 282 ± 7 for the beginning and end of the period, respectively. No intermediate samples were collected. Explanation for the increase in water content of inner bark of the logs and branchless snags must, at this time, be left unanswered. It is possible that the additional water resulted from the continued metabolic activity of the still-living tissues. In undamaged trees the excess metabolic water might be removed by transpiration. This suggestion, however, is contradicted by the absence of a gradual change in water content according to the degree to which the trees had suffered (Table 1).

FACTORS OTHER THAN MOISTURE CONTENT ASSOCIATED WITH HOST SELECTION.—Differences other than those in moisture content were also noted. Cambial activity continued in the snags which retained one or more live branches, for the inner bark continued to separate easily from the wood. In the branchless snags, on the other hand, the inner bark became adherent to the wood—an indication that cambial cell division had ceased. Likewise, a difference in the activity of the resin-secreting cells was noted in the two types of trees. On the branched snags the exposed wood areas, where bark samples had been removed, became coated with resin, whereas on the branchless snags no resin flow occurred; consequently, a black mold soon covered the exposed wood.

As previously mentioned, the activity of microorganisms did not appear to attract *Ips* beetles from a distance. Nevertheless, it may be that some type of decomposition is associated with the attraction of certain host material for nearby beetles. It was found that logs wet with acetic acid, then dried, were more attractive to *Ips* beetles than were untreated logs. By the rapid attraction technique previously described, it was found in 12 tests that the treated logs averaged 4.8 entrances per log as compared to 1.8 for the untreated after an exposure period of 18 hours. The difference necessary for significance at odds of 19 to 1 is 2.21. Buchanan (1941) reported a similar increase in the attractiveness of sections cut from trees injected with ethyl alcohol to an ambrosia beetle, *Xylosandrus germanus* (Blfd.).

Person (1931) concluded that fermenting inner bark was the substance most attractive to the western pine beetle. The moisture content and acetic acid selection tests already mentioned support Person's theory that volatile decomposition products may be associated with initial attraction when the beetles are in the immediate vicinity of uninfested suitable hosts. Fermentation producing acetic acid results also in water production; therefore, *Ips* selection of logs with high moisture content and logs wet with acetic acid is suggestive of relationships that would be worthy of further study.

In all the rapid-attraction tests the logs being tested were always slightly

separated (6 inches) from each other and were not in contact with the cage containing the attractant. In one test, however, pairs of short log sections were tested by standing one on the other. For half of the 10 replicates the treated (acetic acid) logs were placed on top and for the remainder the untreated logs were on top. After an exposure period of 18 hours the difference in the number of entrances in treated and untreated sections was not significant. This observation indicates that the odoriferous attraction was not discernible by the beetles when the treated logs were in contact with those untreated.

The moisture content of the inner bark also appeared to influence the selection of host material by species of *Monochaumus*. In 13 logs which had inner-bark moisture percentages of 316 to 448, there was a total of 21 egg niches cut by sawyers (*Monochamis*), whereas there were no sawyer egg niches in the 10 logs with moisture contents of 132 to 300 per cent. Another series of 6 soaked logs had 33 sawyer egg niches after having been exposed for 15 days, whereas there was only 1 niche in the 6 dried logs and no attacks on the 6 untreated logs.

EFFECT OF INNER-BARK MOISTURE ON BROOD SURVIVAL.—A few observations were also made on the effect of inner-bark moisture on *Ips* brood survival. The work was done with several snags in which attacks were just starting. The tree boles were cut into 1-foot lengths and treated as previously described, so that a range of moisture conditions was obtained. Two moisture determinations were made for each log. The first sample was taken 1 week after the log had been treated and waxed, whereas the second was taken 3 weeks later, when the bark was removed for making the final observation. There was a mean difference between the two readings of 57 ± 7 per cent, even though the logs had been kept in an insectary during the whole period. Paradoxically the results obtained (Table 2) show that brood survival was best when moisture conditions did not deviate too greatly from those found in vigorous trees. In the wetter logs each female made a number—as many as 5—short galleries extending from the end of the main tunnel, possibly to escape the unfavorable conditions.

When the logs were debarked and examined, it was found that 1 per cent of the total living population had just emerged, 54 per cent were callow adults, 25 per cent were pupae, and the remaining 20 per cent were larvae.

Table 2.—Production and survival of *Ips* brood in logs of different moisture contents.

Inner-Bark Moisture Content	Brood Produced per Centimeter of Egg Galleries	Brood Survival	Replications
Per cent	*Number*	*Per cent*	*Number*
1–100	0.3 ± 0.1	7	8
101–200	$1.7 \pm .7$	48	2
201–250	$1.8 \pm .2$	48	9
251–300	$1.3 \pm .2$	34	10
301–350	$0.8 \pm .1$	20	13
351–400	$.8 \pm .1$	28	7
401–450	$.2 \pm .1$	6	5
451–500	0	0	2

Of 571 reared beetles, 70 per cent were females.

The number of eggs laid per centimeter of egg gallery ranged from 1.8 to 5.3 eggs, with an average of 3.88 ± 0.01 for the 56 logs.

The *Ips* brood produced per square foot of bark area can be determined approximately by multiplying the production data in table 2 by 97.4.

SUMMARY.—Observations were made on the activities of the bark beetle, *Ips pini* (Say), for the purpose of determining the manner in which it selects and attacks host trees. It was found that the beetles alone were not strongly attracted to suitable host logs, but that, after a few beetles had entered these logs, the logs then became attractive to other beetles. This pattern of attack and attraction progressed at an ever increasing rate until all the space in the host material was utilized or all the beetles within the effective range of the attraction were occupied.

Deviations of inner-bark moisture content—especially an increase—from that found in vigorously growing trees appeared to be associated with increased attractiveness.

After beetles had been attracted to the immediate vicinity of untreated logs and logs wet with acetic acid, the latter were attacked more readily.

Brood survival was best when the inner-bark moisture conditions did not deviate too greatly from that found in vigorous trees.—6-23-48

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EIGHTH INTERNATIONAL CONGRESS OF ENTOMOLOGY, STOCKHOLM

August 8–14, 1948

The total advance and first day registration at Stockholm was 510—possibly 50 of these did not appear during the Congress. They represented 37 countries, the largest delegations aside from Scandinavia, in which I include Finland, were from England, 63; France, 45 and the United States, 24 as follows:.

Annand, P. N.	Huckett, H. C.
Bradley, G. H.	Kaan, Dr. H. W.
Bradley, J. C.	Matthews, Ambassador H. F.
Bradley, Mrs. J. C.	Metcalf, Z. P.
Butt, F. H.	Metcalf, Mrs. Z. P.
Butt, Mrs. F. H.	Moorehouse, Col., USA
Chapin, E. E.	Nelson, F.
Clarke, J. T. Gates	Park, Thomas
Cory, E. N.	Parker, H. L.
Forbes, Wm. T. M.	Parker, Mrs. H. L.
Haller, H. L.	Russell, Louise
Hayes, W. P.	Usinger, T. L.
Hayes, Mrs. W. P.	

These were registered, but so far as I an aware, none of them attended the meetings.

Calvert, P. P.	Dos Panos, C. F.
Curran, C. H.	Dos Panos, Mrs. C. F.
Johannsen, O. A.	Sherman, J. D.

The opening session in the Music Hall was addressed by the Prime Minister of Sweden, T. Erlander, Dr. Trajurdh, the President, the President designate, M. Jeannel and Dr. Jordan, the Permanent Secretary. It was announced that the next meeting would be held in Amsterdam in 1951. Prior to the meeting the invitational letter of Dr. S. A. Rohwer was presented to the Executive Committee, a very select group which included Dr. Bradley, representing Dr. Johannsen. A commitment had been made at Berlin in 1938 that precluded acceptance of the U.S.A. invitation.

The meetings were held in the Eastern High School, an ancient building without our concept of modern and adequate facilities. There were eleven sections, one devoted to arachnids. It was difficult to keep track of the progress in the sections in order to hear the papers one wanted to hear, which in the case of the writer was in most cases, those delivered in English. Many addresses were in French and most of the Scandinavians used English or German. Although Italian is an official language, Professor Silvestri spoke fluently in English.

The entertainment was outstanding in every way. Each day at noon a bountiful repast with aqua vita, beer, wines and liqueurs was arranged at some famous restaurant (an international word apparently), museum or slot (castle). These affairs lasted for two to two and one-half hours, after which scientific sessions were resumed from 3:30 to 5 P.M. and then similar affairs were scheduled for the evening. Trips by bus, train and boat to points of interest took up a good deal of the time and enabled one to become better acquainted with fellow members. On one occasion the cocktail party given by Ambassador Matthews conflicted with the Congress and in an endeavor to make an appearance at both parties a group went riding in a taxi on a wild goose chase without catching up with the main party which had gone to Drottningholm by boat.

The trip to Uppsala and the home of Carl von Linné occupied an entire day. Most of the members of the congress went by train, but the writer was fortunate in being the guest of Standard Oil through the courtesy of Franklin Nelson and Frederik Haagberg. After lunch at Flustret in Uppsala, a famous restaurant, the name of which means "the entrance to the beehive," we saw at our leisure Linné's home, attended another repast at the University of Uppsala and returned with Captain Strid to his home where Annand, Haler and Professor and Mrs. Butovitch were entertained at a supper of many courses and nearly as many kinds of drinks with much "skolling" that lasted from 6 to 12:30.

As hosts, the Swedes cannot be exceeded. They did everything possible to make the stay in Stockholm exceedingly pleasant. The sessions were profitable, especially from the contacts made with foreign entomologists and the opportunities to learn how they work and to see their collections and laboratories.

E. N. CORY

Observations on Nosema Disease of Honey Bees

C. F. Burnside and I. L. Revell,[1] *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Until a few years ago beekeepers in this country believed that Nosema disease was of only minor importance. Outbreaks of this disease were thought to result from poor beekeeping practices, especially poor wintering conditions for the bees. Recent studies have shown that Nosema disease causes large economic losses to the beekeeping industry. In Europe this disease has long been considered of economic importance.

Nosema disease is caused by a single-celled protozoan parasite, *Nosema apis*. When the spores (resting stage) are ingested by the bees with food or water, they germinate within the bee's stomach (ventriculus or mid intestine), producing motile planonts. Planonts multiply and invade the epithelial cells lining the stomach. The parasites multiply within these cells and pass through additional stages of development, so-called meronts, sporoblasts, and young spores, and finally mature spores are produced. The new crop of spores is liberated within the stomach when the epithelial cells rupture. The spores pass on into the rectum and are voided with the feces, thus becoming a source of spreading the infection.

Karmo & Morgenthaler (1939) reported that Nosema disease develops best at 86° to 93° F., more slowly at 68° to 77°, and not at all at 50° or 98.6°. They think early brood rearing favors the disease.

Lotmar (1944) reported that Nosema disease develops best at temperatures which are most favorable for brood rearing. Below 86° F. and at 96.8° it increases more slowly or abnormally, and it ceases to develop at 98.6°. Infected bees recovered when they were kept at 98.6° for 10 days.

Farrar (1942, 1944, 1947) reported that Nosema disease contributes to the loss of bees and queens, particularly in package-bee colonies, and that hot summer temperatures check its spread.

The present studies were made to determine how temperature affects the development of Nosema disease and how the disease affects honey bees. The work was started at Beltsville, Maryland, in 1942 and continued at Laramie, Wyoming, from 1943 to 1947.

About 300 cages, each containing approximately 125 bees, were used for the cage tests. Results obtained with bees in cages, however, are often not directly applicable to colonies of bees or must be interpreted with caution. About 600 colonies of bees also were used for tests and observation in these studies.

The bees used for most of the cage tests were taken from colonies in which no Nosema-infected bees were detected in a sample of 50 bees. The cages of bees were kept at temperatures ranging from 51° to 99° F. Each cage was supplied with a vial of sugar sirup and one of water. Inoculum was made by mixing approximately a million Nosema spores per cubic centimeter with the sirup. For other cage tests bees were taken from naturally infected colonies and were not inoculated. The death rate was recorded daily.

At Beltsville the time required for *Nosema apis* to produce the first crop of mature spores at a given temperature after bees were inoculated was used as a measure of how rapidly the parasite developed at that temperature. At Laramie the parasites were counted by the method commonly used for counting bacteria, and the time required for the first parasites to mature was observed. Samples of 10 bees were usually used for counting the parasites. Table 1 shows the number of parasites in the stomachs of bees kept at different temperatures for different periods at Laramie.

Results obtained at Beltsville indicated that the optimum temperature for *Nosema apis*—the temperature at which the organism develops most rapidly—is about 89.6° F. At Laramie, however, the first mature spores appeared a little sooner at 88° than at 89.6° at Beltsville. Table 1 also shows that *N. apis* multiplies most rapidly at 88°, which is approximately 6° below the most favorable brood-rearing temperature. A wide temperature range is favorable for its growth. This finding conflicts with Lotmar's report (1944) that Nosema disease develops best at tempera-

[1] A contribution from the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, in cooperation with the University of Wyoming.

Table 1.—Average number of Nosema parasites in the ventriculus of artificially inoculated and naturally infected bees caged at different temperatures for different periods at Laramie, Wyoming.

Temperatures, °F.	Days Caged	Parasites per Bee
Artificially Inoculated Bees		
51	9	None
	16	None
57	7	70,101
	14	245,371
65	7	116,095
	14	5,483,592
	21	3,978,216
	28	5,526,160
	35	3,815,681
	42	4,256,846
75	7	3,467,478
	14	19,321,475
	21	17,833,432
88	7	4,550,955
	8	4,380,682
	9	9,167,698
	13	26,748,472
	14	41,585,516
	16	32,259,768
	21	17,770,397
	28	9,713,348
	35	8,194,429
94	7	3,397,735
	14	15,254,988
	21	14,637,481
95	7	2,368,354
	14	8,084,137
	21	8,121,192
97	7	7,739
	14	1,129,999
	21	989,874
98	7	541
	14	24,871
	21	25,232
99	7	None
	14	None
	21	None
At 88° for 7 days plus—		
65	7	23,699,023
	14	8,745,883
	21	5,533,899
	28	6,810,953
94	7	15,092,454
	14	7,711,021
	21	8,645,408
	28	603,698
95	7	11,525,101
	14	6,098,899
	21	5,479,721
	28	1,842,053
97	7	6,036,982
	14	464,363
	21	317,326
	28	208,972
99	14	None
At 94° for 14 days plus—		
88	7	13,203,962
	14	7,476,569
	21	13,091,736
At 95° for 14 days plus—		
88	7	11,114,237
	14	7,485,309
	21	14,782,865
At 97° for 14 days plus—		
88	7	6,389,131
	14	9,256,705
	21	3,958,705
At 94° for 7 days plus—		
99	14	None
Naturally Infected Bees[1]		
97	7	340,547
95	7	4,620,613
94	7	6,207,255
97	14	425,684
95	14	7,321,775
94	14	11,044,580
88	14	14,573,893
65	14	8,312,459
97	21	69,657
95	21	11,119,397[2]
94	21	7,105,063
88	21	12,209,676
65	21	10,541,499
94	28	5,905,407
65	28	6,566,159

[1] 90 per cent of the bees infected with an average of 14,093,852 spores per bee when the tests were started.
[2] Only 3 bees were used for this count.

tures which are most favorable for brood rearing.

More counts of parasites in bees kept at 88° were made, and the results compared with those obtained for the same period at other temperatures. Growth is sharply diminished at temperatures near the maximum (between 98° and 99°) and the minimum (between 51° and 57°). At 88° the maximum number of parasites was reached after about 14 days. After 21 days, however, a marked decline was noticed, and after 28 and 35 days there was a further drop. This decline was probably due to destruction of epithelial tissue by the immense number of parasites, which left less food for their continued development. At less favorable temperature the maximum number of parasites was lower, less epithelial tissue was destroyed, and little or no decline in numbers was noticed. When bees were changed after 7 days at 88° to a lower or higher temperature, increase in the number of parasites gradually slowed down. Parasite counts were not always consist-

ent when bees were changed to 88° after 14 days at a higher temperature, but usually there was an increase.

Bees that became infected at 88° or 94° F. recovered completely when kept for 14 days at 99°. When changed again to 88°, they were still free from infection after 7 days, but after 14 days infection had reappeared in 10 to 20 per cent of the bees in some cages (not shown in Table 1). Reappearance of infection is thought to have been caused by spores voided with the feces after the change was made. These results confirm those of Lotmar (1944) that Nosema-infected bees recover when kept at a temperature above the maximum for growth of *Nosema apis*.

Just as occasional individuals among other forms of life escape infectious disease for unexplained reasons, even when heavily inoculated or intimately exposed, so does an occasional bee escape infection by Nosema disease even though heavily inoculated and kept at a temperature favorable for the disease.

When naturally infected bees were placed in cages and kept at different temperatures (Table 1), there was only a slight increase in the number of parasites in bees kept at 88°. The indication was that these bees were at nearly optimum temperature for Nosema while within their colony, and that temperature had the same effect on Nosema disease in both naturally infected and artificially inoculated bees.

At Beltsville the maximum temperature for development of *Nosema apis* appeared to be about 3° lower and the minimum temperature about 3° higher than at Laramie, and the disease developed more slowly at brood-rearing temperature than it did at Laramie. Tests showed that this difference was not due to the difference in relative humidity at the two stations. Laramie is 7000 feet higher than Beltsville, and has considerably lower humidity.

Nosema-diseased bees in cages showed a rise in death rate above that of checks (healthy bees) within 16 to 40 days after they were inoculated. The average length of life of check bees from four colonies kept at 88° F. ranged from 34 to 58 days after they were caged. The average for bees from the same colonies that were inoculated with Nosema on the day they were caged ranged from 25 to 48 days. Table 2 shows further details of these tests.

Nosema disease shortened the life of bees in cages from 10 to 40 per cent. Different cages of check bees from the same colony lived for about the same time. Different cages of diseased bees from the same colony also lived for about the same time but died sooner than the check bees. When the bees in different cages were taken from different colonies, the length of life of check bees, as well as of diseased bees, sometimes varied considerably. Both the check and diseased bees from good colonies of long-lived bees lived longer in cages than did those from poor colonies of short-lived bees. Bees from different colonies of the same breeding were usually much more constant in their longevity than were bees from colonies of different breedings.

Table 2.—Comparison of the length of life of healthy and Nosema-infected bees kept in cages at 88° F. at Laramie.

Colony	Condition of Bees	Days Before Disease Caused Rise in Death Rate	Length of Life in Days	
			Maximum	Average
A	Diseased	37	62	46
		37	62	46
		37	66	46
		37	65	46
	Healthy	No rise	78	51
B	Diseased	40	68	40
		40	65	42
	Healthy	No rise	85	58
C	Diseased	24	47	29
	Healthy	No rise	87	50
D	Diseased	20	40	25
		18	35	23
		18	38	23
		16	37	22
	Healthy	No rise	65	34

During hot summer weather with temperatures ranging up to 100° F. at Beltsville, two strong, apparently healthy colonies were each fed a gallon of sirup containing approximately 5 million Nosema spores per cubic centimeter. Three similar colonies in the same group were retained as checks. Seven days later young Nosema parasites were found in an occasional bee among samples from both inoculated colonies. After 14 days 10 per

cent of the bees in one inoculated colony and 20 per cent in the other showed advanced Nosema disease. A single infected bee was found among samples taken at the entrance of a check colony, but this bee could have drifted from an inoculated colony. One month after the inoculations no infected bees were found in any of the colonies.

The natural longevity of bees in colonies was studied during weekly inspection of more than 600 colonies throughout the active seasons from 1942 to 1947. From a study of the number of eggs laid and the amount of brood reared, as well as the population of adult bees and the amount of honey and pollen stored, differences in the longevity of adult bees in different colonies were apparent. Only the significant facts determined from these observations are recorded in this paper.

At times worker bees in different colonies were found to vary considerably in their natural longevity. Good colonies built up rapidly in the spring and had a strong force of field bees by the time the main honey flow started. The bees in these colonies were found to be relatively long-lived, and a large proportion of the adult worker population became old in appearance.

At the other extreme, poor colonies built up slowly even though they had an equal start in the spring and the queens appeared to be equally prolific layers. Adult worker bees disappeared from these colonies about as fast as young bees emerged, and the worker population never increased much beyond the number needed to care for the brood. The entire force of workers always consisted of young-appearing bees.

Most of the colonies were between these two extremes in longevity of worker bees and colony development. The amount of the surplus honey crop was roughly proportional to the longevity of the worker bees in the colonies.

It was observed that continued inbreeding shortens the average longevity of worker bees, but there was considerable variation in this respect among individual inbred colonies of the same breeding.

These observations confirm those of Borchert (1940), who by marking bees and liberating them in colonies observed that bees from different colonies differed in their longevity. Borchert also marked Nosema-diseased bees and found that they did not live so long as healthy bees in the same colonies. White (1919) observed that colonies which were heavily infected with Nosema failed to build up, became weaker, or died. There is also abundant additional evidence in the literature that Nosema disease shortens the life of bees in colonies.

In the present work a higher percentage of Nosema-infected bees was nearly always found among the sick and dying than among the healthy-appearing bees from the same colonies. Colonies with heavy Nosema infection had a higher average death rate and made a poorer showing than did colonies with relatively few infected bees.

Although Nosema disease shortens the life of bees in colonies, some colonies with 80 to nearly 100 per cent of the bees infected continued to build up satisfactorily, while others with about the same percentage of infection built up more slowly, many of them becoming weakened or even dying.

After settled warm weather arrived and Nosema subsided in all colonies, those colonies which continued to build up while infection was heavy were observed to have longer-lived bees than did colonies which were weakened by the disease. Colonies with long-lived bees produced larger populations of field bees and larger honey crops than did colonies with relatively short-lived bees.

DISCUSSION.—The average temperature of broodless bees in winter is well below the most favorable temperature for Nosema disease. In the spring, when a small amount of brood is being reared, a large proportion of the bees in colonies are likely to be exposed to temperatures that are highly favorable for the development of Nosema. During this period infection spreads most rapidly. At the peak of brood rearing, after settled warm weather has arrived, the temperature of the brood next (93° to 95° F.) is above the optimum for Nosema disease. At this time of year infection subsides. The seasonal rise and fall of Nosema disease coincides with seasonal changes in weather throughout the country, whether these changes come early or late.

The wide variation in the life span of both healthy and Nosema-infected bees in different colonies appears to be highly

significant in determining the economic importance of Nosema disease. The fact that some heavily infected colonies were able to tolerate Nosema disease and to build up rapidly while others weakened or died may help to explain differences in opinion regarding the importance of this disease. Nosema disease retarded the development of colonies in a degree depending upon the percentage of bees infected and the ability of the bees to tolerate the disease and continue their normal activities. When infected bees lived for a long period, the effects of Nosema were not readily apparent. When they lived for only a short period, the colonies were retarded, weakened, or killed, depending upon the percentage of infection. Colonies that became weaker when infection was heavy were the poorer colonies with short-lived bees that would not have equaled the good colonies even if they had not been infected. The longevity of bees in colonies, as well as in cages, was observed to depend largely upon the stock of bees. Different colonies of the same breeding were much more constant in longevity of the worker bees than were colonies of different breeding. Bees that had been inbred for several years did not live nearly so long as bees that had not been inbred.

No way to control Nosema disease has been found. It may be possible to reduce losses from the disease through selection and breeding for longer-lived bees, which will be able to build up their colonies in spring even when most of the bees are infected by Nosema disease.

SUMMARY.—Studies were made at Beltsville, Maryland, and Laramie, Wyoming, from 1942 to 1947 to determine how temperature affects Nosema disease of honey bees and how this disease affects the bees.

Nosema apis develops most rapidly at about 88° F., but it develops fairly well within a wide temperature range. The maximum temperature lies between 98° and 99°, and the minimum between 51° and 57°. Development is retarded at brood-rearing temperature (93° to 95°) and at temperatures of broodless bees in winter. Diseased bees recover when kept at 99° for 14 days.

The life span of both healthy and diseased bees in different colonies varies considerably, whether the bees remain in their colonies or are removed and kept in cages. Different colonies of the same breeding varied less in longevity of the bees than did colonies of different breeding. Continued inbreeding shortens the average life of worker bees, but inbred colonies of the same breeding vary in this respect. Good colonies with long-lived bees continue to build up in the spring even when heavily infected. Poor colonies with short-lived bees fail to build up, become weaker, or die when infection is heavy. Colonies with long-lived bees produce stronger forces of field bees and store more surplus honey than do colonies with short-lived bees. It may be possible to reduce losses from Nosema disease through selection and breeding for longer-lived bees that will be able to build up their colonies in spring even when most of the bees are infected.—4-8-48.

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The appointment of Doctor Edward H. Glass as Associate Professor of Entomology at the Geneva Experiment Station has been announced by the office of Station Director Arthur J. Heinicke. Dr. Glass will work primarily with insect pests of fruit.

Hive Humidity and Its Effect Upon Wintering of Bees[1]

EDWIN J. ANDERSON, *State College, Pennsylvania*

This study was initiated in an effort to determine the basic reason for periodic heavy winter losses of bees in Pennsylvania. The need for such a study was indicated by records of annual winter losses which varied greatly from year to year. The losses ranged from an occasional low of 5 per cent to a high of 45 per cent during the winter of 1935–36.

The records of 1935–36 showed excessive losses not only for unpacked colonies but also for an occasional apiary in which the bees were packed for winter. Hive moisture and molding of combs and food supplies had often been observed to be excessive especially in late winter; hence, it was felt that this moist condition might be one of the causes of winter losses, either directly or indirectly by encouraging the development of adult bee diseases.

Excess hive moisture is brought about largely through the conversion of honey into heat, carbon dioxide and water. The moisture tends to remain in the hive in winter and spring when the bees are clustered in order to retain heat. During this season they are unable to fan out the damp air and air condition the hive as they do in summer.

Because of the close relationship between temperature and humidity, it was deemed advisable to study first, the relationship between external and internal hive temperatures for colonies wintered in different ways so that the effects of hive temperature upon hive humidity could be more closely evaluated. The temperature studies were not considered as a problem in themselves but as having a possible indirect bearing on hive humidity.

Empty hives with a constant source of heat were used for the first part of this study. Living colonies were not used since the effect of external temperature variations upon internal hive temperatures could, it was felt, be determined more accurately in empty hives free from the unknown factors introduced by the bees. A 15-watt electric light bulb was placed in each of the hives, in the first series of experiments described in this paper. By using all bulbs of the same wattage a relatively constant quantity of heat was provided for each hive. The bulbs were placed 1 inch from the bottom and 3 inches from the center of the rear wall of each hive. Temperature readings were obtained by inserting a laboratory thermometer through a hole bored through the front center of standard 10-frame hives 0.5 inch below the lid or 2.5 inches below the top of the hive body. Each thermometer was pushed through the opening so as to extend approximately 6 inches inside the hive. The inside dimensions of the single-story, 10-frame hives used were 18.25 by 14.75 by 10.25 inches. The light bulb was approximately 10.75 inches from the thermometer bulb. All temperature readings were made in Fahrenheit and are so written in this paper.

The first set of hives, equipped with the 15-watt bulbs and thermometers, was composed of a series of six new, empty, unpacked hives set up to check the accuracy of the arrangement and learn the extent of variation that might be expected when all conditions were as nearly the same as possible. Readings were made every hour, then every half hour, from 8:30 A.M. to 3 P.M. The readings indicated some variation in temperature curves for individual hives. In a number of instances, however, the curves followed the same or nearly the same pattern during the time-temperature intervals under observation. The first readings, as will be seen in figure 1, indicate that variations are not excessive for hives heated and arranged in the same manner.

The number "10" is used to indicate outside temperatures on all tables and graphs of this paper.

In order to check any possibility of difference between actual hive temperature and the effect of radiated energy from the light bulb, two thermometers were placed in one hive. Each thermometer was located 0.5 inch from the front center of the hive, 2.5 inches from the top, 6 inches from the outside wall and 10 inches from the light bulb, One thermometer was shaded with a piece of galvanized iron covered, on the thermometer side, with black tire tape, the other was exposed to

[1] Authorized for publication on February 20, 1948 as paper No. 1431 in the Journal Series of the Pennsylvania Agricultural Experiment Station.

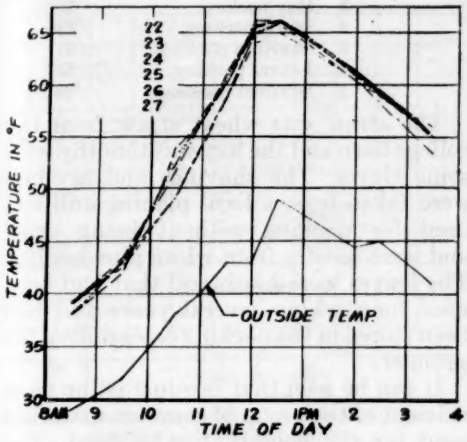


FIG. 1.—Comparative temperatures in unheated hives.

the light of the bulb. Readings were taken periodically but no significant differences in temperature were observed for the two thermometers.

Temperatures and time intervals were as follows:

Time	Temperature of shielded thermometer	Temperature of exposed thermometer
1:30 P.M.	85°F.	85°F.
2:30 P.M.	86°°	87°
3:30 P.M.	85°	85°
4:30 P.M.	81°	81°
5:30 P.M.	77°	77°

Readings were made in degrees and half degrees only, no effort was made to divide a degree into smaller fractions.

It was also thought advisable to check temperatures at different levels within the hives. To do this, a series of thermometers were arranged in the front of a hive; they were numbered and arranged so that No. 1 was 2.5 inches from the bottom of the hive, No. 2 was 4.5 inches from the bottom, No. 3 was 7.25 inches from the bottom, and No. 4 was 10.25 inches from the bottom and 0.25 inch from the top. All thermometers extended 6 inches inside the hive. Readings and time intervals were as follows:

Thermometer No. 4 was approximately 0.25 inch from the inner cover of the hive; hence, a lower temperature was recorded by this thermometer on the first, third and last readings. It will be observed that the temperature difference between the top and bottom of the hive was very little. This condition probably accounts for the limited air loss that was indicated by only slight temperature and humidity changes when a small top entrance was added to a hive with a bottom entrance as is shown by an analysis of figures 2 and 3.

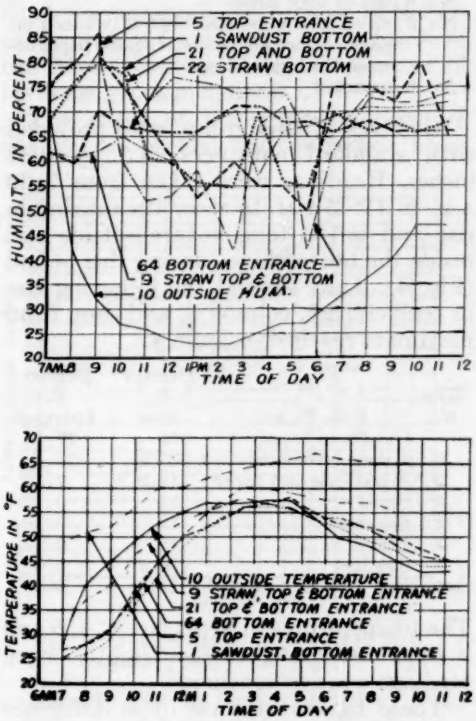


FIG. 2, (*above*) and 3 (*below*).—Comparison of temperatures with varied packing of hives and varied arrangement of entrances.

The second set of controlled hive conditions included six hives packed with the most common packing materials plus straw and hay. One unpacked hive was

DATE	TIME	TEMPERATURE OUTSIDE HIVE	DISTANCE FROM BOTTOM OF HIVE: 2.5″	4.5″	7.25″	10.25″
			Hive Temperature			
11/15/45	11:00 A.M.	78° F.	86½°	87°	88°	87½°
11/15/45	12:00 noon	76°	87°	87½°	88°	88°
11/15/45	3:30 A.M.	68°	82°	83°	83½°	83°
11/16/45	7:00 A.M.	44°	56°	56½°	57°	57½°
11/17/45	8:00 A.M.	72°	82½°	83°	84°	83°

included in the set. A 15-watt bulb and a thermometer were placed in each in the same manner as in all hives of this series.

The following tabulation indicates the hive number and type of packing material used. Packing material between the wooden boxes or cases and the hives was distributed as follows: 4 inches on the bottom, 5 inches on all sides and 6 inches at the top.

No. 1 packed with sawdust
No. 2 " " shavings
No. 4 " " leaves
No. 5 " " hay
No. 9 packed with straw
No. 3 placed in a wood case with a two-inch air space and two pieces of corrugated paper between the hive and case
No. 6 unpacked

All hives of this group were provided with standard entrances, 4.5 by 0.32 inches. Readings were taken from 7:30 A.M. to 11:15 P.M. to show the maximum rise and fall in temperature outside and inside the heated hives during this period (Fig. 4). They showed the following rise in temperature, column 3, and drop from maximum reached, column 4.

Hive No.	How Packed	Degrees F. Rise	Degrees F. Dropped
	Outside of hives	25	17
6	Unprotected hive	23.5	15
3	Wood case and paper	19.5	7.5
9	Straw	13	0
2	Shavings	13	0
4	Leaves	13	0
1	Sawdust	12.5	0
5	Hay	11.5	0

The temperatures in hives No. 2, 4, 5 and 9 were continuing to rise slightly when readings were discontinued.

These figures indicate little difference in temperature range for hives packed with different types of packing material. The hive in a wooden case with paper packing showed a greater temperature range than did the hives packed with the other materials. There was, however, a significant difference in the maximum temperature reached where different types of packing material were used.

The higher temperatures indicate the more efficient materials for packing. The following is a listing of the packing materials used and the maximum temperatures recorded for this series:

No. 10	Outside of hives	56° F.
Hive No. 6	Unpacked	62.5°
3	Wood case and paper	68°
5	Hay packing	70°
9	Straw packing	73°
2	Shavings packing	81°
4	Leaves packing	83°
1	Sawdust packing	88°

The straw was wheat straw from the college barn and the hay was timothy with some clover. The shavings and sawdust were taken from a local planing mill and used for packing without being dried and were mostly from white pine lumber. The leaves were hardwood that had been used for packing several years and had been stored in the packing cases during the summer.

It can be seen that sawdust is the most efficient of the group of common materials used for the conservation of heat. The wood case with a 2 inch air space and corrugated paper is the least efficient but is the cheapest to buy and build and requires the least labor in packing bees for winter.

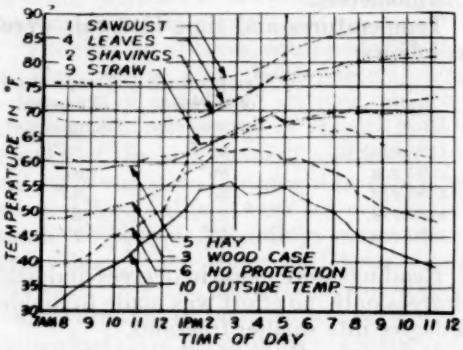


FIG. 4.—Temperature responses in unheated hives to change in outside temperatures.

Figure 4 shows an almost immediate temperature response inside an unprotected hive to temperature changes outside the hive (No. 6). On the other hand, packed hives required from 6 to 9 hours before outside temperatures made significant differences within the hive (No. 2). The wood case (No. 3) is an exception; it showed an immediate but gradual temperature change as compared to very little temperature variation for the packed hives.

Figure 5 shows a similar set of curves for the same group of hives but includes, in addition, a second unpacked hive and one wrapped in water-proof paper. The graph made from the readings of this group taken from 6:40 A.M. to 5 P.M. shows that the paper wrap on No. 7 pro-

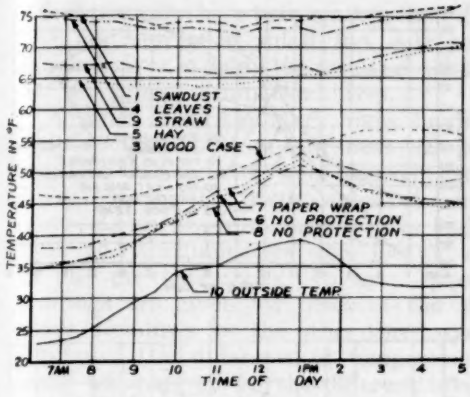


FIG. 5.—Comparative effect of different types of packing on hive temperatures.

vided only a small amount of insulation. Its greatest value probably was due to wind protection. No. 3, or the hive in a wooden case with corrugated paper, showed for a second time, a gradual rise and fall in temperature. This type of packing offered less protection than is provided by hives packed with hay or straw (Fig. 5).

The fourth set, composed of three hives, was left unpacked. All hives were arranged the same except for a cheesecloth box placed in one of the three. The box was made of heavy cheesecloth to enclose a space 14 inches long, 10 inches wide and 9 inches high. It was placed so as to occupy about the same space as would be occupied by a normal cluster of bees in winter. Both the electric bulb and the thermometer were placed in the cloth box in the same location as in the other hives. Subsequent readings indicated that the amount of protection offered by the cloth was considerable. The temperatures inside the cloth (Fig. 6, No. 35) remained 20° F. higher, most of the time, than did that in the other two hives. The cloth provided considerable heat conservation but not as much as did the packing material in a packing case. Temperature variations were, however, nearly as great as in the unprotected hives which was not the case for packed hives where the temperature varied but little and required hours before noticeable changes were recorded inside. No practical application of this method of protecting the winter cluster seems available because of the arrangement of frames and combs inside of the hive. Readings from this group of hives are given in figure 6.

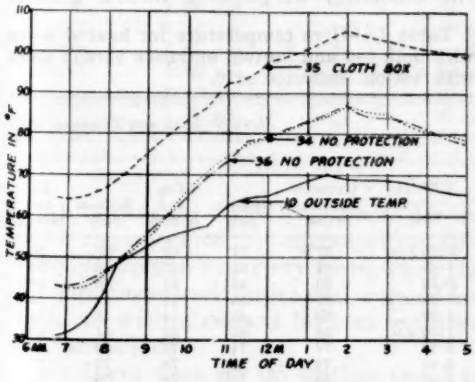


FIG. 6.—Value of a cloth box for protection from temperature changes.

The effect of honey on temperature changes in packed and unpacked hives was checked in the fifth set of hives. This series was conducted to learn the effect on wintering that might be expected from leaving more or less honey with the bees in the fall. Five combs containing 26 pounds of honey were placed in a packed hive, and a similar amount in an unpacked hive. Temperatures in these hives were compared with similar hives not containing honey. The hive packed with shavings and provided with honey (No. 2, Fig. 7), showed a temperature rise of only 11° F. as compared to 23° for hives packed with leaves, sawdust or hay but without honey. A similar effect was observed when honey was placed in an unpacked hive (Fig. 8, No. 6). The hive containing honey showed a temperature rise of 23° and a drop of 4°

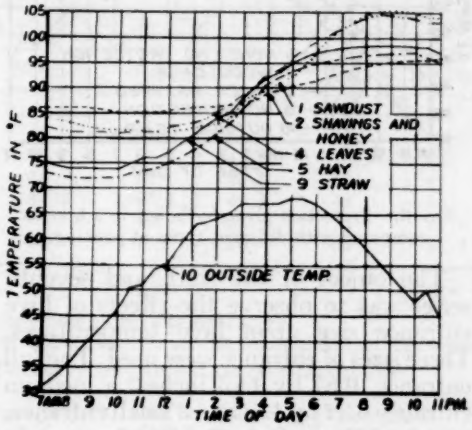


FIG. 7.—Temperatures within packed hives containing honey. (See Fig. 8.)

from 7 A.M. to 11 P.M. as compared to a temperature rise of 44° and a drop of 27° for a hive without honey (No. 8). During the same period the outside temperature rose 37° and fell 23°. It would seem from these results that the honey acted as a governor in retarding the rate of temperature changes in the hive and should be of a considerable value to a colony of bees by giving them more time to form the winter cluster when outside temperatures drop rapidly. More complete results for the two groups of hives are given in figures 7 and 8.

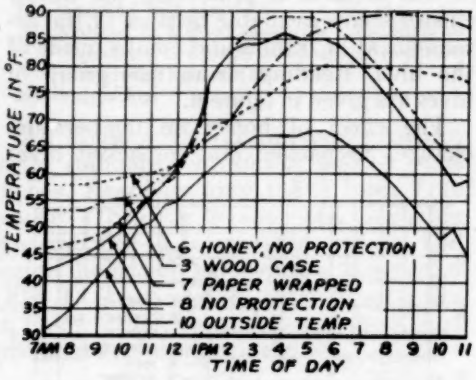
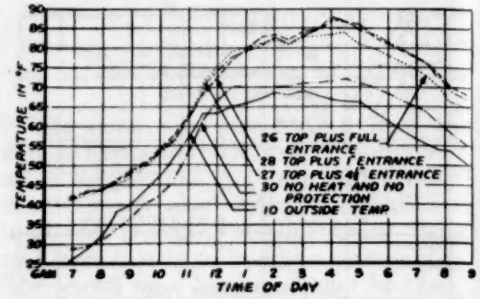


FIG. 8.—Protection given by honey in a hive as compared with different types of packing.

The object of the sixth and seventh series was to observe the effects of hive entrance size upon hive temperatures. Three sizes of entrance were used: The full entrance, 0.87 by 14.5 inches; a medium entrance 0.32 by 4.5; and a small entrance, 0.32 by 1 inch. Only small differences in heat loss were observed in either group regardless of entrance size (Figs. 9 and 10). A more serious loss of heat occurred when wind blew against a full entrance as is shown in figure 8. Figure 7 included one hive (No. 30) which was not heated, to show the correlation between the inside and outside temperature when an unheated hive was used as a check.

Set No. 8, the last of this series, was run to compare temperature variations in hives provided with both a top entrance and bottom entrance as against hives containing only a bottom entrance. The top entrance was 0.625 inch in diameter and the bottom 0.32 by 4.5 inches.

Very little was known regarding the actual effect upon temperature or humidity when a top entrance was added to a hive with a bottom entrance. Some believed that air currents were set up which greatly increased heat loss and brought about the death of the colony. Readings showed, on the contrary, that effects upon hive temperatures were limited and very similar to those obtained from entrance size variation. Only a small drop in temperature could be attributed to the addition of a top entrance. No difference in the temperature curve could be observed following the addition of a top entrance to a packed hive. In one packed hive, the colony with a top entrance remained warmer than one without, indicating that the efficiency in packing had a greater


TEMPERATURE IN °F
26 TOP PLUS FULL ENTRANCE
28 TOP PLUS 1" ENTRANCE
27 TOP PLUS 4½" ENTRANCE
30 NO HEAT AND NO PROTECTION
10 OUTSIDE TEMP.
TIME OF DAY

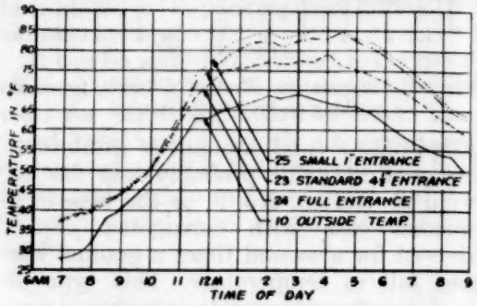


FIG. 9 (*above*), and 10, (*below*).—Effect of hive entrance size on hive temperatures.

Table 1.—Hive temperature for heated hives with both top and bottom entrance versus hives with bottom entrance only.

		Hive Number and Temperature			
		4	5	7	2
3/30/44 Time	Outside Temperature	Bottom only	Top and bottom	Bottom only	Top and bottom
6:30 A.M.	27°F.	34	34	32	30
8:20	34	37	37	36	36
9:45	39	42	41	40	42
10:30	37	45	44	42	45
12:00	39	46	44	43	44
1:30 P.M.	58	55	53	51	49
3:10	72	74	71	69	67
4:45	72	80	78	75	79
6:45	69	77	76	73	74
8:10	65	73	72	70	69
10:25	50	63	63	60	60

effect upon the hive temperature than did the addition of a small top entrance. Table 1 gives in detail the results obtained for this group of unpacked hives.

A series of six two-story hives, having only standard bottom entrances was set up. Two thermometers were placed in each hive, one in the front center of each story, 2.5 inches from the top. The light bulb and thermometers were located as in the previous series. To save space, readings are given for three of the six hives. Readings for the other three were similar. Little difference in temperature could be observed for the different hives or for the location of thermometers in the hives (Table 2).

two 0.875 inch holes bored into the top front of the hives, one on each side 2 inches from the top of the upper super. The third group of two hives had standard bottom entrances and top entrances consisting of a single 0.875 inch hole bored in the front center of the super 2 inches from the top. Here again very small temperature differences could be attributed to the addition of the top entrances as is indicated by the results given for one hive of each group (Table 3). All hives were protected against prevailing winds.

After completing the series of experiment described above, a second series of hive conditions was tested. The second series differed from the first in that full

Table 2.

Date	Time	Outside Temperature	Hive Number and Temperature					
			1		2		3	
			Top	Bottom	Top	Bottom	Top	Bottom
1947								
1/12	3:00 P.M.	32° F.	42	42	42	42	41	41
1/13	11:00 A.M.	36	45	45	45	45	46	45
1/13	1:30 P.M.	39	46.5	46	47	46.5	48	47
1/13	5:00 P.M.	32	42.5	42.5	42.5	42.5	43	42
1/16	8:30 A.M.	19	32	32	32	32	33	32.5
1/16	11:30 A.M.	29	38	38	38	38	39	38.5

Table 3.—Hive entrance and its effect on hive temperature.

Date	Time	Outside Temperature	Temperature and Entrance Arrangement					
			Two Top and One Bottom		One Top Plus One Bottom		Standard Bottom	
			Top	Bottom	Top	Bottom	Top	Bottom
1947								
1/27	8:30 A.M.	12° F.	26	25.5	25	24.5	27	26.5
1/27	1:30 P.M.	36	28	27.5	28	28	29.5	29.5
1/28	8:30 A.M.	4	16.5	16	17	16	18	18
1/28	1:30 P.M.	16	24.5	24	24	23.5	25	25
1/28	5:00 P.M.	18	28	28	28	27.5	28.5	28
1/28	8:30 A.M.	8	20	20	20.5	20	21.5	21.5
1/29	1:30 P.M.	21	27.5	27.5	29	28	29.5	29.5
1/29	5:00 P.M.	24	31	31	31	30.5	32	32

An additional check was made to observe the effect of top entrances on hive temperatures in two-story hives when the top entrances were larger and were added to hives with standard bottom entrance 4.5 inches long.

Six hives were set up so that two had standard bottom entrances and two were provided with top entrances consisting of

colonies of bees were used instead of empty hives and no artificial heat was provided.

In the second series, readings for both temperature and humidity were taken. Both packed and unpacked hives were used as were also hives with both top and bottom entrances and some with a top or a bottom entrance only.

Humidity and temperature indicators were installed inside the hives. After being checked, each instrument was attached to a small wood framework and was placed, one above and one below, the combs on which each colony of bees was clustered. The upper instrument was placed below the inner cover and the lid and the lower one above the bottom board. A small trap door was provided in one side of each frame so it could be opened and readings made with a minimum of disturbance to the colony. All colonies were in two-story hives.

It was found that the humidity of the hives remained higher most of the time than that of the air outside and generally was above 55 per cent.

Great fluctuations in humidity were recorded as is indicated by figure 2. The cause for this extreme variation could not be determined, unless it was due to disturbances caused by periodic reading of the instruments every few hours. These readings were made in a colony located in the apiary.

A colony was then moved March 17, 1947 and placed in a well protected location 2 feet from a building. The cluster of bees and brood in this hive extended to the top of the frames and combs. A humidity indicator was placed above the colony in the same type of wooden frame used with the bees in the apiary. The frame was 2 inches deep and fit on the hive the same as a small super. The top of the frame was insulated with one layer of tarred paper, one of corrugated paper and quater-inch boards. All cracks around the frame were filled with putty. The indicator was located about 0.625 inch above the top bars of the frames and above the center of the hive. The space around the indicator was open but protected with a wire screen so the bees could not pass into the area included in the wooden frame. Strips of black friction tape were placed around the indicator to shut off as much light as possible when readings were being made. The tape and insulation were not used with the hives when readings were made in the apiary.

Humidity readings indicated an extremely constant humidity most of the time. The humidity in the hive did not show any relation whatever to the humidity outside the hive. The humidity in the hive stayed at 75 per cent for 10 days without the slightest observable fluctuation, while the humidity outside the hive ranged from 15 to 80 per cent.

The hive was opened on the tenth day and the humidity dropped to 63 per cent, then rose to 66 per cent and fluctuated about a degree over a period of 1 day. A super of honey was removed the following day but the humidity remained at 65 per cent for another day then it rose to 70 per cent. The day following the hive was opened again causing the humidity to drop to 50 per cent for a few minutes when it rose to 65 per cent where it continued for 2 days. The humidity then increased to 75 per cent and continued at 75 per cent for 7 days. The hive was opened a third time causing the humidity to drop to 68 per cent and increase to 70 over a period of 30 minutes. The humidity remained at 70 per cent for 3 days then went again to 75 per cent for 1 day and returned to 70 per cent for 6 days. The humidity finally increased to 80 per cent where it continued for a period of 4 days.

The colony was divided and half of it taken away. The humidity indicator was returned to the single story hive. The humidity stayed at 65 per cent for 4 days, 70 per cent for 5 days, 75 per cent for 3 days then dropped to 45 per cent and returned to 70 per cent over a period of 3 days. This happened without any apparent cause. The humidity leveled off at 70 per cent and continued for 4 days when readings were discontinued.

A second hive was placed alongside the first and the instrument placed on it as on the first. This hive maintained a constant humidity of 65 per cent for a period of 12 days when readings were discontinued.

It was quite evident that when the hive was not disturbed the bees maintained a definite and fairly constant humidity with occasional fluctuations. Temperature and humidity readings made in the apiary showed that both remained higher above than below the cluster. The temperature below the cluster and frames was often lower than outside the hive since the temperature of the hive some distance from the cluster of bees remained near that outside the hive. The normal outside temperature rise in the morning was followed by a temperature rise inside the hive but there was often sufficient lag to make the inside temperature lower for a time than the outside temperature except

for the hive packed with sawdust (Fig. 10).

Humidity tests were also run in the laboratory with mailing cages, each of which contained a queen and six worker bees. The cages with queen and bees were placed in solid wooden bushel boxes that had been coated inside and out with parafine. In each box was placed a humidity and temperature indicator. The humidity was controlled by placing a pan of water in each box. A wooden frame with cheesecloth hanging over it was added to the pan of water. The humidity was controlled by the number of square inches of cloth extending above the water level.

The following approximate degrees of relative humidity were maintained: 22, 30, 42, 50, 60, 72, and 79. Four sets of experiments were conducted, each set containing from four to six cages with queen and bees. The shortest period that any group lived was 4 days. In this box, the humidity was maintained at 75 per cent. Death in this case was caused by the candy absorbing so much moisture that it caused the bees to become smeared with syrup and die prematurely. Table 4 is a summary of results:

Table 4.

Cage No.	Approximate Per Cent Humidity	Number of Days All or Part of the Bees Survived
13	21	8
14	21	12
5	27	23
9	31	30
1	38	9
6	41	22
10	42	10
2	49	19
3	60	15
11	66	20
8	68	7
19	70	21
15	71	12
16	71	12
18	71	16
17	73	27
7	75	4
12	77	5
4	78	10

A review of the results did not show outstanding trends for length of life under different percentages of relative humidity. The higher humidity, except for No. 17, indicates a shorter life span but most of this was due to the food or candy having absorbed excess quantities of moisture and smearing the bees excessively causing death. It would seem, therefore, the excess moisture caused the death of the bees indirectly. This happened in cages Nos. 12, 4, and 7. The bees in cage No. 4 were removed at the end of the third day when they first showed signs of becoming smeared with syrup. By providing a new cage and candy, the length of life of this group of bees became nearly normal.

A summary of results obtained shows that packing maintains a more constant temperature in the hive, conserves heat and reduces the amount of food required for winter use. The even temperature of packed hives often retards brood rearing until later in the season when rearing progresses more rapidly than in unpacked hives. In spite of the even temperature maintained in packed hives, the humidity fluctuated greatly, possibly due to the disturbance caused by reading the instruments.

Hives packed in straw or hay and provided with some ventilation between packing and lid of packing case remained slightly drier than hives wintered in any other way. The humidity curves are, however, as irregular as those for other hives but not as extreme. The combs and pollen supplies in straw or hay-packed hives, where the seal was broken and top ventilation provided, remained relatively free from mold and appeared nearly as clean and fresh in the spring as in fall when packed. Sawdust provided the most efficient packing but did not eliminate excess moisture as did straw and hay.

The greatest humidity variation was indicated in an unpacked hive with a top entrance only. The addition of a top entrance to a hive with a bottom entrance did appear to make a small difference in hive temperature and humidity. The effect observed was greater for humidity than for temperature. There was no parallel between hive humidity and humidity outside the hive. Hive humidity was generally much higher than that of the air surrounding the hive.

Temperature and humidity readings showed little correlation. Temperatures in the hive were continuously responding to fluctuations outside the hive but hive

humidity showed no such parallel. Honey in a hive acts as a governor to retard sudden temperature changes and gives the bees more time to form a winter cluster when outside temperatures drop suddenly.

Bees can withstand the high humidity of the hive with no immediate evidence of ill effects. High humidity, however, does affect food supplies and encourages molding of combs and pollen supplies causing indirect damage to bees and combs. Packing bees with straw or hay reduces hive humidity to a minimum and maintains combs and food supplies in a more wholesome condition. Where hives were insulated above the humidity indicator and readings made with a minimum of disturbance and light penetration, the humidity remained surprisingly steady with an occasional period of fluctuation for which no cause could be found.

No relation could be found between humidity and the prevalence of Nosema disease though a study on a larger scale might provide different results. Hives kept in the unusually dry conditions of the laboratory developed Nosema, as readily as did bees in the apiaries under natural conditions where the humidity was much higher. Nosema was present in many colonies of the College apiaries and gave evidence of being one of the principal causes of winter losses and spring dwindling of colonies.—6-15-48.

Stimulation and Suppression of Some Vegetable Plants by DDT[1]

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Marked changes have been observed in the growth and appearance of various crops treated with DDT for insect control. For instance, certain cucurbits have frequently shown chlorosis, stunting and decreased yields. DDT-treated potato plants, on the other hand, have often shown brighter green, broader, more open leaves, greater vine growth and increased yields. Such beneficial changes in potatoes and other crops following application of DDT in the field have been generally attributed to the elimination of injurious insects.

Heuberger (Anon. 1946a) has observed that applications of DDT to leafhopper-free potato vines caused little difference in vine growth indicating that the phenomenal growth and yields of DDT-treated plants was the result of insect control rather than a stimulation due to the insecticide. Observations by the writers of several experimental potato field plots in Wisconsin have indicated, however, that DDT acted as a growth-promoting substance. It was observed that plants responded more favorably when the concentration and number of applications of DDT were increased within certain limits. Furthermore, apparent stimulation appeared in locations where insect populations were low, and in cases where there was little difference in insect numbers in treated and untreated plots. It was also observed that such plant vigor failed to develop in plots treated with insecticidal materials similar to DDT in effectiveness for insect control.

Other than the brief reference by the authors (Anon., 1946b) to the stimulating effect of DDT to plants, little evidence appears available showing beneficial or detrimental effects of DDT applications on plants grown in the absence of injurious insects. Consequently, trials were made early in 1946 to ascertain the effect of various DDT treatments to insect-free, greenhouse-grown plants.

PROCEDURE.—A wide range of DDT concentrations in dust and spray form were applied to numerous vegetable plants. Dust mixtures containing from 0.01 per cent to 40 per cent DDT were prepared from 50 per cent micronized DDT (minimum setting point 89° C.) blended with pyrophyllite[2] in a ball mill. Spray concentrations ranging from 0.000125 per cent to 8.2 per cent by weight DDT were also prepared from 50 per cent micronized wettable DDT.

The dusts and sprays were applied to each species of plant in a geometric pro-

[1] Chicago Program. Approved by the Director of the Wisconsin Agricultural Experiment Station.

[2] *Pyrax ABB.*

gression with each concentration four times as great as the preceding one. The entire series of concentrations was employed on all plants except for the omission of the lower levels on very resistant plants and the higher ones on very susceptible plants.

Dusts were applied to the plants in uniform, measured amounts with a precision dusting apparatus. The insecticide was dispersed with an air blast of 20 lbs. pressure per square inch and allowed to settle on the plant in a settling tower. The sprays were applied with a fan-type nozzle fed from a tank with an agitator to insure proper suspension of the DDT. Treatments were accomplished by passing the plants through the spray directed on a constant-speed turntable. Plants received an application comparable to 100 gallons of spray per acre. Usually only one application was made but in some cases plants received two or three treatments.

Squash, cucumber, bean, pea, corn, carrot, potato, and tomato plants were used in the trials. Seeds of these plants were germinated in moistened sawdust and then transplanted to 5-inch pots containing a standard soil compost. The seedlings were grown in the greenhouse until small plants suitable for treating had developed. Plants in early stages of growth responded most readily to treatment and uniform young plants of this type were selected for testing purposes. Three replicates of three plants each were treated with the various concentrations of DDT in spray or dust form. Following treatment, plants were usually held for observation and measurement up to or corresponding to the blossoming period.

Differences occurring between treated and untreated plants were measured by recording plant height, width and area of leaf, distance between internodes, number of blossoms, weight of plants, general vigor and color and the amount of chlorosis and necrosis that appeared.

EXPERIMENTS AND RESULTS.—Most plants were injured by the applications of high concentrations of DDT. it was possible, however, to establish reduced levels at which no injury occurred and the plants were stimulated. The degree and type of injury and stimulation depended upon the susceptibility of the species of plant and the form and method in which the DDT was applied.

Cucumber.—Cucumber plants (Straight Eight variety) were among the most susceptible to DDT injury of those tested. Dust concentrations above 10 per cent DDT produced injury approximately two days after treatment. Injury appeared as chlorosis of the leaves which advanced from the margins inward but did not change the normal green color of the veins (Fig. 1D). The margins of these leaves characteristically turned upward. The lower and more severely damaged leaves became distorted, stunted, and necrotic. The growing point was sometimes similarly affected even to the extent of complete necrosis. Plants were also generally stunted (Fig. 1C), possessed smaller leaves, shorter internodes, and at the higher DDT concentrations, produced practically no blossoms.

Corresponding concentrations of DDT sprays caused greater damage than the dusts. Sprays produced a more distinct mottling followed by greater distortion and necrosis of the leaves and growing point. This mottling may have been due to the effect of the accumulation of spray droplets on the leaves as compared with a more general distribution of the insecticide applied as dusts. DDT dissolved in various solvents and applied as emulsions produced still greater injury than the suspensions.

Only slight chlorotic injury appeared on cucumber plants when dusts were reduced to one per cent DDT. Sprays at slightly lower levels gave a faint mottling effect. At still lower concentrations a general stunting of plants was perceptible only when they were closely compared with untreated checks.

As DDT was reduced to levels below those mentioned above, a stimulation of the treated plants occurred. This stimulation increased progressively to a point of maximum plant response when the DDT was applied at the rate of about 0.16 per cent in a dust (Fig. 2) and 0.0005 per cent in a spray (Figs. 1C and 3). When reduced beyond these points the stimulatory effect was decreased until no effect was noticeable at extremely low limits.

All parts of the plant appeared to be equally stimulated by DDT as indicated by the many methods of measurement employed. The height of the plants, however, gave a reliable index of the general stimulation and this method of measure-

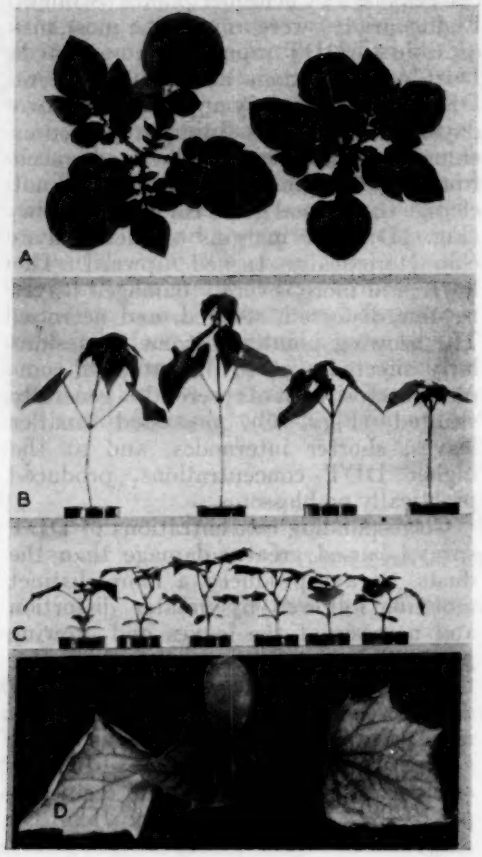

FIG. 1.—Effects of DDT applications to some vegetable plants. Potato plant (A) on left showing signs of stimulation following two applications of ten per cent DDT dust. Untreated plant on right. Bean plants (B) from left to right received zero, 0.032, 0.512, and 2.05 per cent DDT sprays. Cucumber plants (C) from left to right received zero, 0.000125, 0.0005, 0.002, 0.032, and 0.128 per cent DDT sprays. Cucumber plant (D) showing characteristic chlorosis and upward turning of the leaf margins following a heavy application of ten per cent DDT dust.

ment was consequently most commonly used. A comparison of the beneficial effects of DDT on the various parts of the plant is discussed later.

Bean.—The higher levels of DDT greatly reduced the rate of growth of Bountiful bean plants within a 24-hour period. However, other injurious symptoms were not apparent until several days after treatment. Two weeks after application of high DDT mixtures (10 to 40 per cent in dusts or 0.512–2.05 per cent in sprays) plants showed marked dwarfing, the growth above the primary leaves being short and bunchy as compared with the untreated plants (Fig. 1B). The affected leaves were small, chlorotic and showed distortion and crinkled margins. Unlike cucumbers, where the veins of the leaves remained green, vein-clearing occurred in beans followed by a general mottling and chlorotic condition which involved the entire leaf. Cotyledonary buds appeared on many plants where retardation of other growth had occurred. As in the case of cucumbers, the bean plant was more susceptible to the sprays than to the dusts. Only a slight distortion and chlorosis of leaves appeared following the application of a 5 per cent DDT dust and still less at concentrations of 2.5 per cent. DDT levels below 2.5 per cent dust or 0.128 per cent spray showed little evidence of injury on the plants. Further dilutions caused a stimulation of the plants. Maximum response to DDT was reached at a concentration of 0.64 per cent dust (Fig. 2) and 0.032 per cent spray (Fig. 1B and Fig. 3). Stimulation became less and less evident as the DDT concentrations were reduced beyond the point giving maximum growth until at very low dilutions no changes were evident in the plants in comparison with the checks.

Trials with caged bean plants in the field showed slightly less injury from DDT than greenhouse-grown plants. However, the concentrations giving maximum stimulation were approximately the same.

Potato.—Triumph potatoes were treated with DDT concentrations up to 40 per cent dust and 8.2 per cent spray. Potato plants showed more resistance to DDT injury than most other plants tested. No

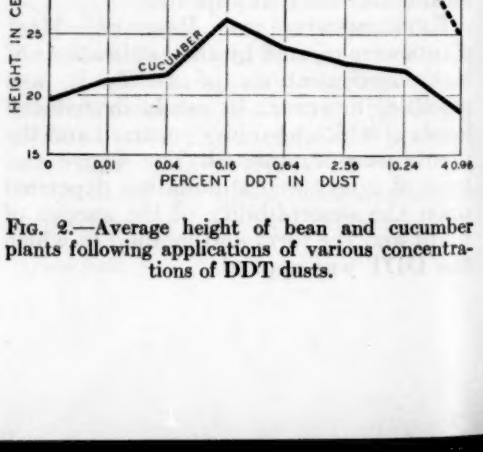

FIG. 2.—Average height of bean and cucumber plants following applications of various concentrations of DDT dusts.

injury was apparent on potatoes sprayed with DDT concentrations as high as 2.05 per cent (16 lbs. per 100 gallons) (Fig. 3) but a small reduction in size of plants and a chlorosis of the lower leaves occurred at 8.2 per cent spray (64 lbs. DDT per 100 gallons). In dust treatments no injury was evident at DDT levels as high as 40 per cent.

Stimulation was not as marked following one application of DDT on potatoes as shown in many other plants treated. This was also true of other plant species showing marked resistance to DDT injury such as corn, carrot, and pea.

Only slight differences in potato foliage were noticed following one application of DDT, but after a second treatment definite stimulatory effects were observed. Figure 1A shows the effect of two applications of a 10 per cent DDT dust to potato plants. The treated plants were taller with larger, brighter green, broader leaves which bulged outward apparently due to the excess growth of the central part. Untreated plants developed smaller, narrower and more pointed leaves of duller color than the treated ones.

A specific concentration of DDT giving maximum stimulation to the plants could not be as clearly demonstrated with potato as with the more susceptible plants such as bean and cucumber. However, indications of stimulation of potato plants occurred at DDT concentrations from 2.5 to 40 per cent dust and 0.008 to 2.05 per cent spray (Fig. 3). Sprays of 8.2 per cent DDT, however, gave a slight reduction in size of plants as compared with the checks.

Squash.—Hubbard squash plants were approximately as susceptible as cucumber to DDT injury. At levels of 2.05 per cent DDT in sprays the growing points were killed, the plants usually greatly stunted, and the leaves distorted with necrotic margins. Unlike cucumber the squash leaves were chlorotic especially along the veins and the central portion of the leaf commonly bulged outward. Some distortion, yellowing and general stunting was also evident at 0.128 per cent DDT. Little evidence of injury was apparent at greater dilutions except for a general reduction in plant size as compared with the untreated checks. Injury was much less pronounced following application of dusts than sprays. Dusts containing 40 per cent DDT produced chlorosis only in the form of vein clearing, slightly bulging leaves and a general reduction in size of the plants. Plants were slightly reduced in size by dust concentrations as low as 0.16 per cent DDT.

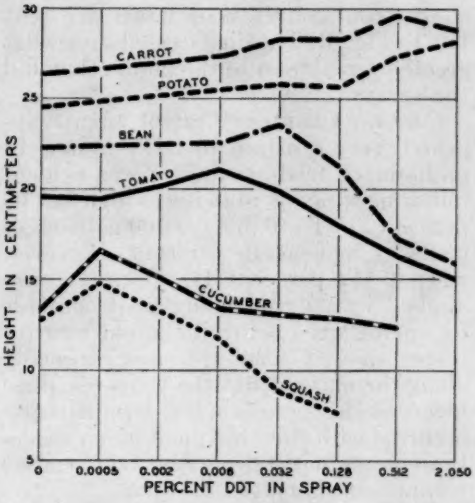

FIG. 3.—Average height of some vegetable plants following applications of various concentrations of DDT sprays

In the preliminary tests some evidence of stimulation in squash plants appeared at concentrations of DDT as low as 0.01 per cent in dust and 0.0005 per cent in spray (Fig. 3). The stimulated plants were taller, possessed larger leaves, were more vigorous in appearance, and produced more blossoms than the untreated plants.

Tomato.—Common varieties of tomato plants were slightly less susceptible than cucumber to DDT injury but more susceptible than beans. The leaves, to which high concentrations of 0.512 per cent to 2.05 per cent DDT sprays were applied, became mottled and wrinkled rather severely. The lower leaves showed a general chlorosis and the plants were considerably reduced in size. Although the dusts caused less distortion of the leaves than the sprays, a distinct mottled chlorosis appeared except for the leaf veins which remained green. Chlorosis and a slight distortion of leaves were noticeable at 2.5 per cent DDT dust, and some reduction in size of plants was also apparent at this level.

Maximum stimulation of tomato plants was reached at concentrations of dust containing about 0.16 per cent DDT and

sprays containing about 0.008 per cent DDT (Fig. 3). The dust caused somewhat greater stimulation to the plants than did the sprays.

Carrot.—Chantenay carrot plants appeared very resistant to DDT injury. In preliminary trials no injury was evident following sprays containing as high as 2.05 per cent DDT (16 lbs. per 100 gallons) or dusts as high as 40 per cent. However, when 0.512 per cent DDT sprays were applied in a dry-cleaning fluid, suitable for carrot weed control, the older carrot leaves showed some chlorosis especially along the margins but the veins remained green. Slight necrosis of leaf terminals also occurred with this treatment. Such a solution containing 0.128 per cent DDT caused no apparent damage.

As observed in other types of plants which were resistant to DDT, it was difficult to establish a definite DDT concentration which gave maximum stimulation to carrot. Some stimulation in carrot plants resulted from dust applications containing 0.16 per cent to 40 per cent DDT. DDT sprays caused a gradually increased stimulation from 0.008 per cent up to a maximum at 0.512 per cent DDT (Fig. 3). Even at 2.05 per cent DDT in sprays the plants showed considerably more growth than the untreated check plants.

Pea.—Alaska pea plants were very resistant to DDT injury and they also showed little response to this insecticide in increased growth. No significant differences appeared on pea plants sprayed with DDT levels ranging from 0.0005 to 2.05 per cent. Similarly dusts containing 0.01 to 40 per cent DDT produced only slight indications of stimulation to the plants and no injurious symptoms.

Corn.—Golden Cross Bantam corn showed no evidence of injury from DDT treatments when levels as high as 40 per cent dust and 2.05 per cent spray were applied. Occasionally a slight yellowing developed beneath spray droplets of DDT. Similarly corn showed little increased growth response to the DDT applications. Plants receiving the highest concentrations of spray or dust mentioned above were slightly larger, however, and weighed a little more than the untreated check plants.

STIMULATION TO VARIOUS PARTS OF THE PLANT.—As indicated earlier, DDT applications stimulated the entire plant with no part receiving benefit at the expense of another. The height of plants was usually used as an index of the general stimulation and to determine the reliability of this measurement the degree of stimulation of various other parts of the plant was considered.

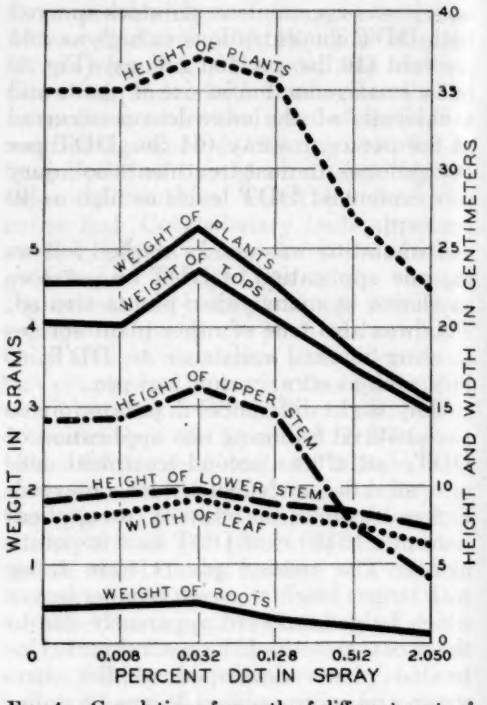

FIG. 4.—Correlation of growth of different parts of bean plants following applications of various concentrations of DDT sprays. All parts show maximum growth at the DDT concentration giving maximum plant height.

At the level of DDT producing greatest height, bean plants (Fig. 4) showed the greatest weight of roots, weight of tops, elongation of the stem both above and below the primary leaves and greatest width of leaves. Figure 5 shows that the greatest number of blossoms was produced at the point giving maximum height to the plants. In addition, at the peak of stimulation, plants appeared more vigorous and produced leaves which were more flattened and brighter green in color than the untreated checks.

Cucumber plants responded similarly to beans in the above-mentioned respects. For instance the number of blossoms on nine plants receiving 0.512 per cent DDT spray was one, 0.002 per cent DDT (which produced maximum height and leaf area)

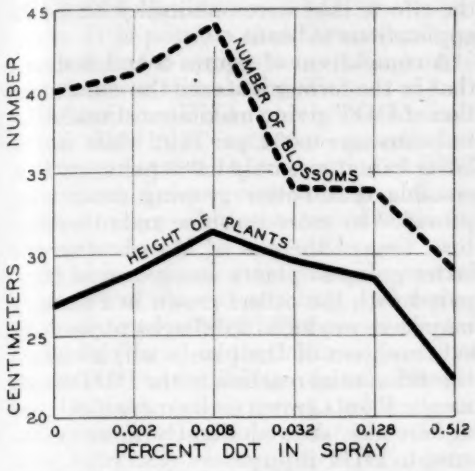

FIG. 5.—Correlation in number of blossoms produced on nine plants with average height of the plants following treatment with various concentrations of DDT sprays.

was 34, and no spray was 17. Dusts produced similar but less pronounced changes in the plants than the sprays.

STIMULATION BY DDT APPLICATIONS TO THE LOWER LEAVES.—Plants stunted by high concentrations of DDT usually grew out of the injury if the growing point had not been damaged. About three weeks after treatment such plants began to grow even faster than the checks or those plants which were originally stimulated. Thus the differences in size of plants, given various DDT treatments, tended to disappear. This indicated that the DDT from the lower leaves was being utilized by the upper part of the plant to produce more rapid growth.

To determine whether the upper part of the plant would show a beneficial effect resulting from applications to the lower parts, cucumber and bean plants were given DDT treatments to the lower leaves only. The smaller upper leaves and growing point of the plants were protected by paper caps. The upper portions of dusted plants were protected by cleansing tissue caps secured to the plants by Scotch tape. Sprayed plants were protected in a similar manner but the caps were made of waxed paper to exclude the spray materials. This protection excluded treatment from all but the lower three or four leaves on the cucumber and the two primary leaves on the bean plants. The day after treatment the caps were carefully removed from the plants so as to prevent the spray or dust material from coming in contact with the upper portion of the plants.

Preliminary trials with cucumbers were made with spray concentrations of 2.05, 0.512 and 0.128 per cent DDT and dusts of 40, 10 and 2.5 per cent DDT. Two weeks after application all treatments showed greater plant growth than untreated checks with the exception of the 2.05 per cent spray (16 lbs. DDT per 100 gallons). The amount of stimulation increased with both dusts and sprays as the amount of DDT was reduced. Dusts produced greater plant growth than the sprays which may have been due to less shock to the plant from applications of dusts than sprays.

The lower leaves became necrotic especially at the higher concentrations. The leaves above the point of application, however, looked extremely healthy, bright green, and flattened. These were similar in appearance to the leaves on plants in previous trials which were stimulated by much lower concentrations of DDT applied to the entire plant. The number of blossoms produced also increased proportionally to the height of the plants. No blossoms were present on nine plants treated with 2.05 per cent DDT, two on those treated with 0.512 per cent and 13 on those treated with 0.128 per cent. Similarly with dusts, the blossom counts were five for 40 per cent, 12 for 10 per cent and 15 for 2.5 per cent DDT.

In further tests it was found that the maximum point of stimulation for cucumbers with protected tops was 0.32 per cent DDT spray. This concentration was 64 times as much as that giving similar results when the whole plant was treated (Fig. 6).

STIMULATION BY DDT APPLICATIONS TO THE ROOTS.—To determine the effect of DDT applied to the roots, 50 per cent wettable powder was mixed with moistened sawdust at the rate of 100, 25, 6.25, and no pounds of DDT per acre. The sawdust was placed in shallow pans to the depth of one inch. Corn, bean, and cucumber seeds were planted in each of the various DDT concentrations.

All seeds in DDT-treated sawdust were delayed in germination. The highest DDT concentration caused a delay in germination of five or six days. However, following in this initial delay, the plants in DDT

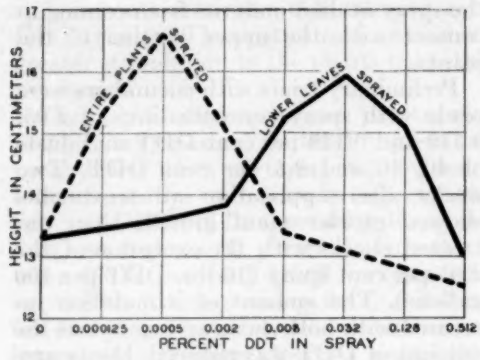

FIG. 6.—Stimulation of cucumber plants by DDT applications to the entire plant as compared with applications to the lower leaves only.

plots grew more rapidly than the check plants and within a month corn plants in sawdust with 100 lbs. of DDT per acre were one to two inches higher than the check plants. The beans were slightly higher than untreated plants but cucumbers made less growth than the checks at this high concentration. At the lower levels of DDT the plants showed some stimulation of growth but this was not quite sufficient to catch up to the untreated plants.

These trials would indicate that DDT is taken into the plant through the roots to cause plant stimulation when the proper DDT concentration is used.

DISCUSSION.—As observed by Allen (1947), the action of DDT on plants closely resembles that of some plant hormones. The effects of nonherbicidal concentrations of 2, 4-D on the growth and development of bean plants as described by Stromme & Hamner (1948) are almost identical with the response of beans to DDT treatments. The top growth was inhibited temporarily and then became more vigorous than that of the untreated plants in both cases. There was also a similarity in the effect of 2, 4-D and DDT in the production of more extensive lateral growth. Delay in maturity was occasioned following the use of both materials. In field trials with potatoes the blossoms were produced later, were much more numerous and remained on the plants about 10 days longer than those on plants treated with insecticides other than DDT. The maturity date was delayed about 2 weeks which again approximates the effects that were obtained with 2,4-D applications to beans.

A comparison of figures 3 and 5 shows that in the former instance the concentration of DDT giving maximum stimulation to beans was 0.032 per cent while in the latter case it was only 0.008 per cent. It is possible that better growing conditions, provided by more sunshine and other factors, toward the end of March when the latter group of plants was grown as compared with the others grown in February may have produced a different physiological condition of the plants which caused the differential reaction to the DDT treatments. Plants grown under more ideal conditions also showed slightly more resistance to DDT injury.

The more rapid growth of plants receiving high concentrations of DDT and the falling off in rate of growth of stimulated plants some time after treatment, indicate that, in the originally stimulated plants, the DDT had become more diffuse in or on the larger plants so that at the later date it was below stimulating strengths. On the originally stunted plants however, the DDT concentration probably had been gradually reduced by the death of the lower leaves, which prevented further absorption through them, and by the greater size of plant so that any given point the DDT was probably now at stimulating levels.

Figure 5 shows a great difference between the DDT concentrations giving maximum stimulation when entire plants were sprayed as compared with applications to the lower leaves only. It is probable, however, that similar amounts of DDT were taken into the plant at each of the points giving maximum stimulation. The amount of DDT available to the plants with protected tops would be limited by the reduced area treated and by the necrosis of these lower leaves which would prevent further absorption through them. Thus stimulating amounts of DDT were probably taken into the plant when DDT concentrations were used which had previously caused stunting.

Plants showing resistance to DDT injury such as potato, carrot, corn and peas, also showed little stimulation, especially with only one DDT treatment. Potato, carrot and corn have shown indications of stimulation in the field but this

occurred following several DDT applications. It is possible that these plants require repeated applications of the insecticide to show stimulating effects.

SUMMARY.—Field observations indicated that DDT acts as a growth-promoting substance. A wide range of DDT dusts and sprays consequently was applied to a representative series of insect-free, greenhouse-grown plants.

At high concentrations most plants were injured and showed stunting, deformity, chlorosis, and necrosis. The plants treated could be placed in the following order of decreasing susceptibility: squash, cucumber, tomato, bean, carrot, potato, pea, and corn. The last four plants mentioned were extremely resistant to DDT injury.

As the DDT concentration was reduced injury disappeared and plant stimulation occurred at a definite level for each plant species. The amount of DDT required for maximum growth was very low for squash and cucumber (0.0005 per cent DDT spray), intermediate for tomato (0.008) and bean (0.032) and high for carrot and potato (0.512 or higher). Peas and corn showed little injury or stimulation following one application of DDT. Similar results were obtained with dusts but the effects were usually less pronounced.

All parts of the plant showed greatest development at those concentrations of DDT producing greatest plant height.

Stimulation of the upper part of the plant occurred following DDT applications to the lower leaves and roots. Those concentrations of DDT, which caused injury to entire cucumber plants, produced stimulation when they were applied to the lower leaves. Bean, corn, and cucumber seeds, planted in DDT-treated sawdust, were delayed in germination but subsequent growth was more rapid than that of the untreated checks.

The effects of DDT on plants closely resembles that of some plant hormones. —7-11-48.

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ARMY AND NAVY EXPRESS APPRECIATION TO DR. ANNAND

Dr. P. N. Annand, Chief of the Bureau of Entomology and Plant Quarantine, has been presented a Citation by National Defense, signed by Secretary Robert P. Patterson and Secretary James Forrestal, which reads "The War Department and the Navy Department express to Percy N. Annand their appreciation for an outstanding contribution to the work of the Office of Scientific Research and Development during World War II."

It was under the leadership and direction of Dr. Annand, during the war period, that the many new methods of insect control were developed and made available to the Armed Services for the protection of the health of military personnel by entomologists and other scientists of the Bureau of Entomology and Plant Quarantine. Aerosol "bombs," DDT formulations, and impregnated clothing for protection against insects are just a few of the more notable contributions made by this organization to the war effort.

These developments for war purposes are now making history in better living for all of us in time of peace.

Recent Developments in the Control of Greenhouse Pests by Liquefied-Gas Aerosols

FLOYD F. SMITH, R. A. FULTON, and P. H. LUNG, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

During the last six years insecticides in liquefied-gas aerosols have been tested against various insects in experimental greenhouses at Beltsville, Md., and in commercial greenhouses in Connecticut, Indiana, Maryland, New Jersey, Ohio, and Pennsylvania. Nicotine was found to be twice as effective against the green peach aphid *Myzus persicae* (Sulz.) in an aerosol as in smoke from a widely used combustible powder in a pressure can (Smith & Goodhue 1943). Lorol thiocyanate was effective in aerosols against the cyclamen mite, *Tarsonemus pallidus* Banks, on snapdragon (Goodhue & Smith 1944). DDT aerosols were effective on thrips, whitefly adults, certain aphids, sowbugs, the American roach, ants, and crickets (Smith and Goodhue 1945).

More recent greenhouse studies have shown that DDT aerosols are effective against the greenhouse leaf tier *Phlyctaenia rubigalis* (Guen.), the azalea leaf miner, *Graciliaria azaleella* Brants, the rose midge, *Dasyneura rhodophaga* (Coq.), chrysanthemum midge *Diarthronomyia hypogaea* (Loew), fungus gnats, centipedes and, on some plants, against the broad mite, *Hemitarsonemus latus* (Banks). Limited tests with aerosols containing a benzene hexachloride of high gamma-isomer content indicated that it was highly toxic to aphids and onion thrips, but an unpleasant odor persisted in the greenhouse for several days.

Experiments during the last year with hexaethyl tetraphosphate in aerosols have shown that this material is highly toxic to the active stages of the two-spotted spider mite, *Tetranychus bimaculatus* Harvey, aphids, the greenhouse whitefly *Trialeurodes vaporariorum* (Westw.), and to mealybugs (Smith *et al.* 1947). A wide range of greenhouse plants were tolerant of this material, the exceptions being tomatoes and certain varieties of chrysanthemums. Aerosols containing either DDT or hexaethyl tetraphosphate have been made available commercially, but hexaethyl tetraphosphate is most widely used chiefly because of its effectiveness against the spider mites, a pest almost universally present in greenhouses.

The present paper gives the results of further observations and experiments with aerosols containing DDT and hexaethyl tetraphosphate,[1] and preliminary experiments with tetraethyl pyrophosphate and parathion, both in the laboratory greenhouse units and in commercial greenhouses.

AEROSOL FORMULATIONS AND PREPARATIONS.—Several formulations containing one of the three insecticides discussed in this paper have been tested; the four formulas indicated in Table 1 have been most extensively used. DDT formulas 104 and 86 have been widely used on general greenhouse crops and on cucumber, respectively. Hexaethyl tetraphosphate, being soluble in methyl chloride, was dissolved in this propellent (formula 106). The several lots of parathion varied considerably as to their solubility in methyl chloride; so 10 per cent of acetone was included in this aerosol (formula 151) to make a stable solution.

The procedure for preparing aerosols and filling cylinders has been described elsewhere (Fulton *et al.* 1947).

Table 1.—Aerosol formulations used in greenhouse tests.

INGREDIENT	FORMULA 86	FORMULA 104	FORMULA 106	FORMULA 151
	Per cent	*Per cent*	*Per cent*	*Per cent*
DDT	5	5	—	—
Hexaethyl tetraphosphate	—	—	10	—
Parathion	—	—	—	10
Cyclohexanone	—	5	—	—
Methylated naphthalene	10	5	—	—
Acetone	—	3	—	10
Dichlorodifluoromethane	85	82	—	—
Methyl chloride	—	—	90	80

APPLICATION OF AEROSOLS.—In early experiments the aerosol, in a 1-pound container suspended in the greenhouse, was discharged through a 2-gallon-per-hour oil-burner nozzle (Smith & Goodhue 1945). Later a more practical knapsack

[1] This insecticide contained 21 per cent of tetraethyl pyrophosphate according to analysis by S. A. Hall.

applicator was developed, which consisted of a cylinder holding 4 or more pounds of aerosol solution, a synthetic-rubber charging hose about 36 inches long, a 24-inch length of 0.2-inch pipe, and a 5-gallon-per-hour oil-burner nozzle. The metal parts were of brass, bronze, or stainless steel to withstand the corrosive effect of hexaethyl tetraphosphate.

In dispensing the DDT aerosol the operator need not wear a respirator unless he is irritated by the included solvents. However, because of the toxicity of the other insecticides as well as methyl chloride, the operator applying these materials should follow suitable precautions (Smith *et al.* 1947, 1948) and wear a gas mask with a canister designed for protection against organic vapors and acid gases.[2]

In applying the aerosols with the knapsack dispenser, the operator walks slowly along the aisle and drifts the aerosol into the air above the plants in two beds on each side.

The DDT aerosol is applied at the rate of 100 grams of solution per 1000 square feet, or for a treating period of 40 seconds. The hexaethyl tetraphosphate and parathion aerosols are applied at the rate of 10 grams of solution per 1000 cubic feet during a treating period of four seconds.

The applications may be made in the daytime provided that cloudy weather permits the closing of the ventilators for at least 1 hour. Most applications are made near sundown, when the ventilators have been closed for the night. Treatments at temperatures between 70° and 95° F. have been most satisfactory for hexaethyl tetraphosphate aerosols. Injury on susceptible plants is increased at lower temperatures, and burning of foliage sometimes results at higher temperatures. No temperature limitations have been determined with DDT or parathion. DDT is effective on wet or dry foliage, but the other insecticides should be applied when the foliage is dry and the soil is moist.

EFFECT ON GREENHOUSE PESTS.—*DDT aerosols.*—In the writers' experiments adults of whiteflies, leaf tiers, the azalea leaf miner, the broad mite, and thrips were apparently irritated by the DDT aerosols, particularly when cyclohexanone was used, for they flew or moved rapidly about for a few minutes before tremors leading to paralysis set in. The green peach aphid and the chrysanthemum aphid, *Macrosiphoniella sanborni* (Gill.) were affected more slowly, and colonies survived for several days to 2 weeks. The rose aphid *Macrosiphum rosae* (L.) and the melon aphid, *Aphis gossypii* Glov., were not affected. Sowbugs and centipedes were very susceptible and were killed by DDT residues on gravel or cinders that had been in the bench for several days. The American cockroach *Periplaneta Americana* (L.) and the European hearth cricket (*Gryllodes sigillatus*) Walk., were also killed by such residues.

Hatching onion thrips larvae and adults emerging from pupae or flying from untreated cucumber plants were killed by DDT residues that had been on the foliage for at least 4 days, affected individuals dropping to papers beneath plants. As many as 200 thrips were collected per square foot of paper after treatment. Both adults and larvae of the onion thrips, *Thrips tabaci* Lind, the chrysanthemum thrips, *Thrips nigropilosus* Uzel, and the banded greenhouse thrips, *Hercinothrips femoralis* (Reut.). moved about and fed on both surfaces of foliage and thereby came in contact with the DDT residues. This residual action appeared to last longer in the fall and winter than in late spring and summer, when temperatures were higher. A single application in October so reduced thrips on chrysanthemums that no other treatment was necessary. On cucumbers one application in January protected the plants for 6 weeks, but later in the spring two applications from 7 to 10 days apart were necessary to bring an infestation of thrips under control. On roses a single adult onion thrips entering the bud was observed to deform the flowers and render them unsalable. In a group of rose houses where the loss of flowers varied between 10 and 50 per cent in November 1945, a 96 per cent reduction of thrips resulted from one application, and after a second application 10 days later no thrips or thrips injury was observed in these houses

[2] Parathion and hexaethyl tetraphosphate are extremely poisonous. Care should be taken to avoid contact of the skin with these materials by wearing gloves when handling them and keeping the sleeves rolled down and the shirt collar buttoned. If the skin is accidentally contaminated, it should immediately be washed thoroughly with soap and water. After these insecticides have been applied, the clothing should be removed, and a bath taken with warm water and soap. Care should also be taken to avoid contamination of food and tobacco.

during the remainder of the winter. For whiteflies, azalea leaf miners, greenhouse leaf tiers, and certain other pests three treatments at weekly intervals were necessary to bring infestations under control.

The flower thrips, *Franklinella tritici* (Fitch), invading rose houses in June was not satisfactorily controlled by DDT-aerosol applications made twice weekly or by a 5 per cent DDT dust or an emulsion containing 0.5 pound of DDT per 100 gallons. Apparently the adult thrips entering the greenhouse moved directly to the newly expanded flowers without alighting on treated foliage.

Against Japanese beetle *Popillia japonica* Newm. adults emerging during the winter in rose houses, applications of DDT aerosol in formula 104 were alternated with light dust applications of 5 per cent DDT. Both materials gave rapid kill of the beetles present, and the residues gave protection for 6 to 8 days. The growers preferred the aerosol because it was more rapidly applied and did not stain the foliage.

Hexaethyl Tetraphosphate and Tetraethyl Pyrosphate in Aerosols.—Among the pests occurring in greenhouses that were treated with aerosols containing hexaethyl tetraphosphate, two species of snail, the broad mite, cyclamen mite, the Surinam roach *Pycnoscelus surinamensis* (L.), and spiders were unaffected, whereas the two-spotted mite, the greenhouse whitefly, two species of mealybug, nine species of aphids, and two species of thrips were susceptible. Dosages as low as 0.3 gram of hexaethyl tetraphosphate per 1000 cubic feet were as efficient as higher dosages in killing whiteflies and aphids. Consistently high kills of spider mites were obtained at 1-gram dosages or higher (Smith *et al.* 1947). In later tests kills were obtained of all exposed adults and larvae of the onion thrips on carnation and onions, and of the gladiolus thrips on carnations and gladiolus, but the concealed thrips escaped. After 12 weekly applications of this aerosol in a greenhouse, a few onion thrips, and gladiolus thrips *Taeniothrips simplex* Mor.), were still present.

Aphids survived in such secluded places as curled cucumber leaves, leaves of various plants close to the soil surface, and on the overlapping leaves in tips of Easter lilies, carnations, or young chrysanthemums. Some whiteflies on foliage close to the soil also escaped. Although the spider mites required higher dosages for consistent kill when exposed on leaves, adults and nymphs were killed in plant recesses where aphids and whiteflies survived. The reason for this anomalous behavior is not fully understood.

The Mexican mealybug, *Phenacoccus gossypii* T. & C., on chrysanthemum was killed more readily than the citrus mealybug, *Pseudococcus citri* (Risso), on coleus. In recent tests the citrus mealybug on *Stephanotis* and the grape mealybug, *Pseudococcus maritimus* (Ehrh.), on carnation were not satisfactorily controlled by weekly applications of aerosol in commercial greenhouses. Reports of similar failures on gardenias in other commercial greenhouses have been received.

Because hexaethyl tetraphosphate aerosols rapidly lost toxicity and because they were effective only against active stages of spider mites and adults of whiteflies, suitably timed applications were made. Four-day intervals between treatments permitted the hatching nymphs of spider mites to complete their feeding and enter the first quiescent stage. In January, April, and June, five applications of aerosol at 2-day intervals or four applications at 3-day intervals were required to destroy the active stages of the spider mites and those hatching from eggs on roses and carnations. In one cucumber house maintained at a high temperature, four applications at 2-day intervals were required to reach the mites in the susceptible stages. The maximum incubation period for eggs of spider mites was near 8 to 9 days at the prevailing greenhouse temperatures.

The following schedules of treatments, after the initial series of four applications at 3-day intervals in January or February, were compared in commercial greenhouses in Connecticut, Pennsylvania, and Maryland: (a) No treatments until mites reappeared, at which time four treatments at 3-day intervals were repeated; (b) biweekly applications; and (c) weekly applications. Houses under schedule (a) became reinfested in spots after 5 to 7 weeks during the winter and spring and after 4 to 5 weeks during the summer. Houses treated at biweekly intervals developed local infestations in May and

July and required four applications. Houses in three ranges given weekly treatments beginning in January remained free of mites, while in a fourth range a house with an infested outdoor bed of azaleas near a side ventilator became reinfested in August. Considering the number of applications required under the various schedules, it appeared that weekly or biweekly applications during the winter and weekly applications during the summer gave most satisfactory control of mites. No more material was required than was used by repeated applications at irregular intervals.

Studies were made to compare the toxic action of aerosols containing 1, 5, and 10 per cent of hexaethyl tetraphosphate in methyl chloride. As shown in table 2, high humidity decreased the effectiveness of the three strengths of aerosol against both the foxglove aphid, *Myzus convolvuli* (Kltb.), and the two-spotted spider mite. About the same mortality of the spider mite was obtained with 0.1 gram of hexaethyl tetraphosphate in 5 per cent aerosol as with 0.2 gram in 10 per cent aerosol. However, the insecticide was about 2.5 times as toxic to spider mites in 1 per cent aerosol as in 10 per cent aerosol. The results with respect to the relative toxicity of this insecticide in the three aerosols to the foxglove aphid were not conclusive.

Table 2.—Relative toxicity to foxglove aphids and two-spotted spider mites of hexaethyl tetraphosphate at different strengths in aerosols. (Three replicates.)

Concentration in Aerosol	Dosage per 1000 Cubic Feet	Relative Humidity	Mortality	
			Foxglove Aphids	Spider Mites
Per cent	*Grams*	*Per cent*	*Per cent*	*Per cent*
1	0.08	92	59	53
		75	77	80
5	.1	92	33	48
		75	67	82
10	.2	94	53	50
		75	90	83

Results of similar studies to compare the efficiency of tetraethyl pyrophosphate (the purified distilled ester) and hexaethyl tetraphosphate,[3] both in 1 per cent aerosols, indicated that the former was approximately four times as toxic as the latter (table 3). This result suggests that hexaethyl tetraphosphate contains other toxic principles than tetraethyl pyrophosphate. These tests agreed with results obtained by Ludvik & Decker (1947).

Table 3.—Comparative toxicity of tetraethyl pyrophosphate (the purified distilled ester) and hexaethyl tetraphosphate in aerosols to foxglove aphids and spider mites.

Materials Used	Dosage per 1000 Cubic Feet	Mortality[1]	
		Foxglove Aphids	Spider Mites
	Grams	*Per cent*	*Per cent*
Hexaethyl tetraphosphate[2]	0.04	42	50
	.06	59	68
	.08	77	81
Tetraethyl pyrophosphate	.02	73	81

[1] Average of three series of paired tests.
[2] Contains 21 per cent of tetraethyl pyrophosphate.

Hexaethyl tetraphosphate and tetraethyl pyrophosphate in aerosols are in an anhydrous condition until they leave the nozzle at the time of application in the greenhouse. They differ from spray solutions in which toxicity is lost by hydrolysis when mixed with water before application. Moisture in the air reduces the efficiency of aerosols after application (Table 2). The more thorough and uniform distribution of the insecticide by the aerosol method, coupled with the higher toxicity of the unhydrolyzed ingredient, may account for the efficiency obtained at the low dosages applied. Hexaethyl tetraphosphate in aerosols is effective against mites and aphids at the rate of 0.5 to 1 gram per 1000 cubic feet in commercial greenhouses. At high dilutions in water sprays approximately 3 grams per 1000 cubic feet are required. At more concentrated dilutions when applied with an electric sprayer the dosage was 3.75 ml. (Roberts 1947).

PARATHION AEROSOLS.—Parathion applied in aerosols at the 1 gram per 1000 cubic feet dosage killed a wide variety of insects in greenhouses,[4] including aphids (foxglove, melon, chrysanthemum, green chrysanthemum, and spinach aphids),

[3] Prepared by S. A. Hall.

[4] Some of the information on species affected as obtained in cooperative experiments with C. A. Thomas, at Pennsylvania State College.

greenhouse whitefly adults, thrips (banded greenhouse, gladiolus, and onion thrips), American roach, German cock roach, *Blatella germanica* (L.), Surinam roach, European hearth cricket, strawberry rootworm, *Paria canellus* L., ground beetle, *Harpalus pennsylvanicus* Deg., greenhouse leaf tier, rose leafrollers, ants, baldfaced hornet, *Vespula maculata* (L.), yellow jacket, fickle midge, stable fly, *Stomoxys calcitrans* (L.), house fly, *Musca domestica* L., two-spotted spider mite, spiders (including wolf spiders, house spiders, and the black widow spider, *Latrodectus mactans* (F.), centipedes, cyclamen mite, and sowbugs. It is evident from these tests that aerosols containing this material are toxic to a wider range of pests than is either DDT or hexaethyl tetraphosphate.

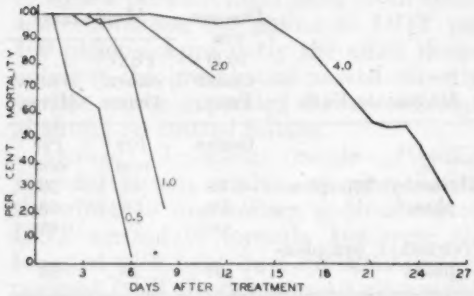

FIG. 1.—Mortality of foxglove aphids due to fumigating action of parathion residues when untreated, infested plants were introduced into a greenhouse previously treated with aerosol at dosages of 0.5 to 4.0 grams of parathion per 1000 cubic feet.

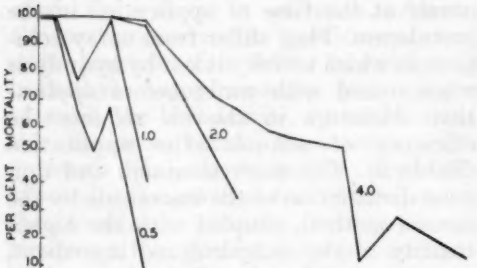

FIG. 2.—Mortality of spider mites due to fumigating action of parathion residues in a greenhouse previously treated with aerosol at dosages of 0.5 to 4.0 grams of parathion per 1000 cubic feet.

Applications were made at dosages of 0.5 to 4 grams per 1000 cubic feet of space in the greenhouse. The material was highly effective at all dosages against the foxglove aphid and the spider mite during the night of application. When untreated infested plants were placed in the greenhouse after application, at night when the ventilators were closed, the residual fumigating action was found to be prolonged as the dosage was increased. At the 4-gram dosage it continued at a high level for at least 17 days against the foxglove aphid and for 6 to 11 days against the spider mite (Figs. 1 and 2).

The toxic residue from a 1-gram dosage on infested plants removed from the greenhouse on the morning after treatment killed all mites that emerged from eggs or from quiescent stages for the next 3 days. At the 2 and 4-gram dosages many eggs and quiescent forms were also killed, and all mites were killed by the one application. In commercial greenhouses the combined effect of residue and fumigating action resulted in complete kill of mites by single applications at dosages of 2 and 4 grams and by two applications with an interval of 7 days at a dosage of either 0.5 or 1 gram per 1000 cubic feet.

EFFECT ON PLANTS.—After application of DDT aerosols to more than 150 kinds of plants being grown in commercial or experimental greenhouses, injury to foliage or flowers was noted only in kalanchoe and cucumber. On kalanchoe symptoms of epinasty and necrosis developed within 2 weeks and progressed until most of the plant was killed back to the ground, but similar injuries are obtained with dusts and sprays containing DDT (Lumsden & Smith 1948). On cucumber slight bleaching of some leaves and yellowish mottling of others developed after treatment of this crop with a DDT aerosol containing cyclohexanone (formula 104). The substitution of a methylated naphthalene as used in formula 86 eliminated this injury almost entirely, and large acreages of cucumber under glass have been treated through two full seasons of thrips activity, with marked increase in growth, quality, and quantity of fruits after destruction of thrips and striped cucumber beetles.

Among more than 180 plants treated with hexaethyl tetraphosphate aerosols, tomato and a few varieties of chrysanthemum were the only plants found to be

injured (Smith *et al.* 1947). Young tomato plants were more susceptible than older ones, and the susceptible varieties of chrysanthemum were more seriously injured if the growth was succulent. Injury on tomatoes appeared in 24 hours as small water-soaked spots, which later became necrotic. Injury on chrysanthemum was first recognized as scattered black dots, which became surrounded by a pale halo. The greater part of the leaf turned yellow with black dots. Brown spots appeared in the flowers of sensitive varieties. Susceptibility to hexaethyl tetraphosphate was exhibited by 30 chrysanthemum varieties in various color groups among 140 tested.

Occasional reports have been received of the burning of flowers and young leaves on rose and carnation or of the spotting, yellowing, and dropping of older leaves on roses. Certain of those reports investigated by the writers appeared to follow either excessive applications of aerosol or treatment at too high temperatures, or both. In other instances, leaf burning, yellowing, and abscission followed the removal of shading on the glass and the recurrence of hot weather. The injuries were worse on the varieties Brandywine and Golden Rapture than on Better Times. Plants growing in constant-water-level beds were uninjured, while the same varieties in adjacent surface-watered beds showed the injuries as described.

Repeated applications of hexaethyl tetraphosphate in liquefied-gas aerosols have resulted in no flower fading as caused by azobenzene. Until late October no atrophied or deformed flowers, termed "bullheads" by the growers, had occurred on roses treated with hexaethyl tetraphosphate in aerosols, similar to that reported from various states (Anon. 1947) or observed by the writers after its application in sprays or by means of fog machines. During November and December such injuries occurred on roses in several ranges but subsequently disappeared.

In rose houses marked increases in vigor of growth followed the use of hexaethyl tetraphosphate aerosols and the consequent elimination of spider mites. The treated plants had a deeper green color, larger leaves, longer and heavier stems, and more and larger flowers. The average stem length of cut roses was increased by 3 to 6 inches, and flower production by 10 to 30 per cent over the previous year. In two ranges the production was approximately fourfold during the three summer months, when mite injury is usually most severe. Improved growth of roses following efficient control of the spider mites by hexaethyl tetraphosphate aerosols was so striking as to suggest stimulatory action beyond the mere elimination of the injury by this pest (Smith *et al.* 1948).

With the adoption of control measures for spider mites by use of azobenzene fumigation or hexaethyl tetraphosphate aerosols, syringing is no longer practiced. As a result the black spot disease has ceased to be a problem on roses, but powdery mildew has become more prevalent and requires special control measures (McClellan 1947).

In tests with parathion on more than 50 commercial greenhouse plants, including tomato and tender varieties of chrysanthemum, that are injured by hexaethyl tetraphosphate, no direct injury was observed except on plants recently treated with sulfur. New growth developing after destruction of mites has been normal in appearance. Insufficient time has elapsed to determine whether the use of parathion will cause sustained increases in growth as does the use of hexaethyl tetraphosphate. The garlic-like odor that persisted in the greenhouse was not detected on cut roses or on those that had been sealed in special cellophane and held for 1 week at 45° F. in a cold room to simulate the commercial practice of prepackaging flowers.

SUMMARY AND CONCLUSIONS.—Observations and experiments with liquefied-gas aerosols were made during the last 6 years in experimental greenhouses at Beltsville, Md., and in commercial greenhouses in Connecticut, Indiana, Maryland, New Jersey, Ohio, and Pennsylvania.

DDT aerosols, which show residual toxic action, were found to be effective against thrips, certain aphids, young of mealybugs, roaches, crickets, sowbugs, centipedes, the greenhouse leaf tier, *Phlyctaenia rubigalis* Guen., the azalea leaf miner, *Gracilaria azaleella* Brants, and the rose and chrysanthemum midges.

Hexaethyl tetraphosphate aerosols were effective against the two-spotted spider

mite, *Tetranychus bimaculatus* Haryey, the greenhouse whitefly, *Trialeurodes vaporariorum* (Westw.), two species of mealybugs, and nine species of aphids, two species of thrips, but not against the broad mite, *Hemitarsonemus latus* Banks or two species of snails. Bodies of affected mites or insects shriveled rapidly after treatment with hexaethyl tetraphosphate, but did not after treatment with tetraethyl pyrophosphate or other materials. The killing action was most rapid with hexaethyl tetraphosphate.

Parathion in aerosol was toxic to the species killed by DDT and hexaethyl tetraphosphate and in addition killed the Surinam roach, *Pycnoscelus surinamensis* (L.), leaf rollers, the cyclamen mite, *Tarsonemus pallidus* (Banks), and spiders. It left a persistent garlic-like odor in the greenhouse and caused a residual fumigation that was toxic to mites, aphids, and other insects. The health hazard to greenhouse workers has not been determined.

For the DDT aerosols, which contained 5 per cent of DDT with dichlorodifluoromethane as the propellent gas, 100 grams of the aerosol solution per 1000 cubic feet appeared to be an adequate dosage. Kalanchoes were injured by DDT in aerosols as well as in dusts and sprays. No injury to foliage or flowers of other greenhouse plants occurred, except on cucumber when aerosols containing cyclohexanone were used. Formulas without this ingredient were devised for cucumber.

An aerosol containing 10 per cent of hexaethyl tetraphosphate dissolved in methyl chloride was applied at the rate of 10 grams of solution per 1000 cubic feet. Experiments indicated that 5 per cent of hexaethyl tetraphosphate in an aerosol was more efficient than 10 per cent. Tetraethyl pyrophosphate appeared to be about four times as toxic to mites and aphids as was hexaethyl tetraphosphate. Plant injury by hexaethyl tetraphosphate occurred on tomato and chrysanthemum, and certain varieties of these crops appeared more susceptible than others. Other plant species, including most of the commercial crops, were unaffected by repeated applications. Roses and other crops freed of mites by regular treatments were more vigorous and productive.

A sample of distilled ester of tetraethyl pyrophosphate in aerosols injured the same plants as did hexaethyl tetraphosphate and also other plants that tolerated hexaethyl tetraphosphate.

The lack of residual action by hexaethyl tetraphosphate is a disadvantage from the standpoint of pest control, but it is an advantage from the standpoint of safety to workers returning to the greenhouse after the termination of each treatment. It has been advantageous in virus studies, since residual toxicity interfered with insect-vector tests conducted with these plants, and the freedom from spider mites has permitted full and unmasked expression of virus symptoms.

The parathion aerosol contained 10 per cent of the active ingredient and 10 per cent of acetone in methyl chloride, and was applied at the rate of 10 grams of solution per 1000 cubic feet. No plant injury followed its application on a wide variety of greenhouse crops except on plants treated with sulfur.

The use of aerosols in greenhouses enables the grower to treat his crops rapidly, efficiently, and with less labor than by spraying or dusting. In general, it also reduces disease spread but tends to permit powdery mildew on roses to become more serious where syringing is no longer practiced.—6-22-48.

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The Cutworm *Loxagrotis albicosta* on Beans[1]

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Scattered reports of cutworm type injury to pinto beans in Colorado have been received for a number of years. A seed dealer in Weld County reported that in 1915 he refused pinto beans from a small area southeast of Greeley because of injury. In 1925, injury occurred at Trinidad in Las Animas County. In Mesa County, injury occurred at Fruita in 1925 and at Mack in 1930. McCampbell (1941) reported losses of 50 per cent in some fields in Mesa County and a control of 40 to 60 per cent by the use of "standard" grasshopper bait under bean shocks.

Since 1941, sporadic injury to pinto beans in Colorado has occurred in Las Animas, Mesa, Delta, Montrose, and Weld Counties. The extent of injury has varied from slight up to 80 per cent.

In the fall of 1945, injured beans were reported from Kimberly, Idaho, by James R. Douglass,[2] Bureau of Entomology and Plant Quarantine, Twin Falls, Idaho. At this time inspectors and commercial seed bean dealers reported that this type of injury had been noticed for about 4 years. The following year, moths reared from worms collected by Douglass in the Blackfoot area were determined as *Loxagrotis albicosta* (Sm.). The Rupert area was also shown to be infested, with injury to beans running as high as 4 per cent.

Specimens of this species in the Colorado A. & M. College insect collection were taken at light traps in Paonia, Ackman and Fort Collins. The oldest record is from Denver, August 13, 1896. One specimen was reared from material collected at Fruita in 1930. H. H. Walkden and D. B. Whelan (1942) report two specimens taken at light traps at Garden City, Kansas in 1934 and seven specimens taken in 1935 and one in 1936 in light traps at Scottsbluff, Nebraska.

The project of determining the identity and life history of the species and working out control measures was started in 1942. Investigations were continued through 1945 and the results were given in annual reports (1942), (1943), (1944,) (1945), to the Mesa County Research Association, a cooperating agency.

Moths of the bean cutworm, reared in field cages and from laboratory material in 1943, were determined by Carl Heinrich of the Division of Insect Identification, Bureau of Entomology and Plant Quarantine, as *Loxagrotis albicosta* (Sm.).

The moth is one of the "handsome" noctuids with a wing expanse of 1.5 inches. The wings are a rich brown color with lighter markings. The costal margin of the front wings is almost white in color. The eggs are dome-shaped about 0.03 inch in diameter, coarsely ribbed and reticulated, and pearly white. The mature larvae are fully 1.5 inches in length, about 0.25 inch in diameter and have a pinkish brown color. The pupae are almost 0.75 inch in length and dark brown in color. Drawings of the different stages and of injured beans are shown in figure 1.

Field cages, 30 inches square, 6 inches deep, with removable screen covers were used in obtaining life history data. The bottomless cages were placed in the soil with 2 inches of the side walls above the ground to support the covers. The covers were kept in place from the time the cutworms were placed in the cages until

[1] Scientific Journal Series No. 264 Colo. Agr. Expt. Station.
[2] Taken from letter of March, 1947, by permission of the writer.

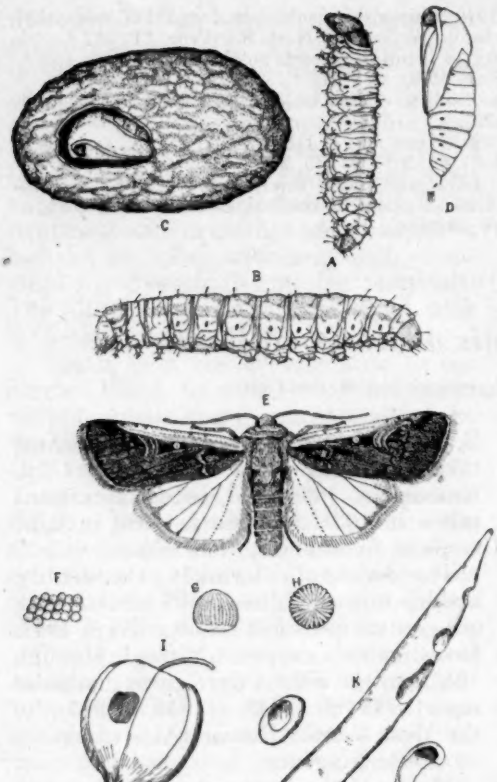

FIG. 1.—A—Overwintering larva; B—Active larva; C—Pupal cell and pupa; D—Pupa; E—Moth; F—Eggs; G—Eggs—side view; H—Egg—top view; I—Injured ground cherry; K—Injured pod and beans. A, B, C, D, E, F, ×1½; G, H, ×6; I, K, +½.

they had entered the soil. They were removed in late fall and replaced the following summer before the moths emerged. A unit of four cages was placed in sandy soil at Mack and a similar unit at Fruita in heavy clay soil.

The cutworms, when full grown in the fall, entered the soil to a depth of 4 to 9 inches and constructed earthen cells in which to pass the winter. The first pupae were found June 26. Moths emerged in the field cages from July 24 to August 17. Eggs are deposited in groups, usually on the under sides of the bean leaves. The number of eggs per group varied from 3 to 79.

Eggs hatched in 7 days and the small cutworms fed on the leaves and buds. These small cutworms stayed continually on the tops of the plants. When they had grown to be about 0.5 inch in length, they started eating holes in the bean pods and when not feeding they burrowed into the soil around the plants.

Cutworms that are not fully grown when the beans are pulled and shocked collect in the soil under the drying beans and feed at night or on cloudy days. If the beans are removed before they complete their development, they feed on shattered beans and on ground cherry fruits.

This insect will feed on several varieties of green beans and on large lima beans when grown close to infested pintos. No native host plant has been found.

Very few of the moths were able to emerge in the cages placed in clay soil. They emerged readily in the cages that were in sandy soil. Moistening of the soil at emergence time by heavy rains or irrigation appears to be necessary, even in sandy soil, before the moths can emerge from the pupal cells deep in the ground. Field observations show that most of the injured bean fields have been on sandy soil. The most injury occurs in the low parts of irrigated fields where the vines are very heavy.

Cutworms may go through the thresher unharmed. Likewise, an occasional cutworm will pass unharmed through the fanning mill of the bean elevator and into the sack with the cleaned beans. These cutworms do not complete their development and consequently are not spread to other areas by this means.

In 1942 baits were made from cryolite or sodium arsenite mixed with bean meal, corn meal, bran, and bran and sawdust. In testing these, the dry or slightly moistened baits were broadcast in bean fields at the rate of 25 pounds dry weight an acre. They were applied in early September before pulling time. Baits used in this way were only partially successful. The best "kill," 60 percent, was obtained by a bait composed of bran 50 pounds, sodium arsenite 1 quart, and white mineral oil, 1 gallon.

Baits, applied under shocked beans at the rate of 30 pounds per acre, were tested in several fields. Examinations were made after 3, 5, and 7 days by moving the shocks, turning the soil with a trowel, and counting the live and dead worms under four shocks from each kind of bait. The seven baits tested included two that were commercially prepared. The best kill of 70 per cent was obtained by a

bait of bean meal 85 pounds, sodium arsenite 3 pints, and water 2 gallons.

Two fields which had been baited early in September with a 50 per cent kill and again baited under the shocks with a 50 per cent reduction of the remaining cutworms, still showed 12 and 17 per cent injury respectively.

The following year, baits including sodium fluosilicate were again tested in the field and under shocks with the approximately equal control results. Fields that had been baited two times showed 12 to 15 per cent of injured beans. Baits, as tested, do not appear to be the answer to this problem.

Control tests, with dusts, were started in 1943. On August 27, five different dusts were applied at the rates of 25 and 50 pounds per acre on half-acre plots. The control in the dusted plots was determined by counting the number of cutworms in 30 feet of row in each plot before dusting and comparing this number with the average number of worms found in a like sample at the end of 7 days. Very few dead cutworms were found in the dusted plots. Basic copper arsenate, 25 per cent, applied at 50 pounds per acre gave the best control of 80 per cent. A small trial plot of DDT 3 per cent, applied at the rate of 30 pounds an acre in 1944 gave 99.8 per cent control.

On August 30, 1945, DDT 3 per cent, basic copper arsenate 25 per cent, and cryolite 33.3 per cent, each mixed with pyrophyllite were tested at Appleton. The DDT dusts were applied at 30 pounds per acre using an 8 row duster. The basic copper arsenate and cryolite were applied in the same manner at the rate of 50 pounds an acre. Just before harvest, samples of beans from each plot were obtained by picking all the pods in 100 feet of bean row. After curing, the samples were threshed in a small hand-operated machine and hand sorted. The average results from five systematic replications of each material are given in table 1.

Table 1 does not include data on injury that occurred after the beans were shocked. The DDT dusts gave the best control and saved about 250 pounds of beans per acre. There were practically no worms under the shocks in the DDT treated plots. Under the shocks in the copper arsenate treated plots there was an average of 12 worms, under the cryolite 21 worms, and under the check 35 worms.

Table 1.—Results of tests for control of the bean cutworm, Appleton, Colo. 1945.

	No. of Injured Beans in 100 Ft. Row	Injured Beans Lbs. per A.	Per Cent Control	Yield of Beans Lbs. per A.
DDT 5%	23.0	2.62	98.13	1849
DDT 3%	47.0	5.41	97.01	1889
Copper Arsenate 25%	878.4	100.40	58.64	1870
Cyrolite 33%	1348.4	154.13	36.04	1963
Check	2166.0	247.59	—	1967

100 feet of row, 32 inches between rows 0.006.
100 average beans weighed .07 pound.

Dusts of 3 per cent and 5 per cent DDT in pyrophyllite were tested under bean shocks for the control of the large cutworms. The dust was applied by means of a perforated pointed nozzle that could be inserted into the bean shock. Two or three puffs of dust from a bellows duster was sufficient to cover the ground under the average bean shock. One field examined 6 days after treatment with 3 per cent DDT showed only two or three live worms per shock. There was an average of 86 worms under the untreated shocks. The 5 per cent DDT gave slightly better control.

In Weld County 1945, two bean fields were treated by airplane using 3 per cent DDT in sulfur. Collected field samples molded to such an extent that the number of injured beans could not be determined. In the untreated portions of the two fields the number of worms found under the bean shocks averaged 12 and 4, in the treated parts of the fields, .8 and .4 worm per shock respectively.

In Montrose County excellent control of the cutworms was obtained in 1946 by the use of DDT 3 per cent dust applied by a 200-horsepower biplane. Later in the season a 75-horsepower monoplane was used with poor results.

Spray tests were started in 1944 at Mack. The bean field used in these tests had been sprayed twice with zinc arsenite for the control of the Mexican bean beetle. Materials tested for the control of the bean cutworm were zinc arsenite, 2 pounds; basic copper arsenate 3 pounds; and cryolite, 6 pounds; each with 100 gallons of water in one and two applications. One application of DDT, 1 pound actual,

Table 2.—Results of tests for the control of the bean cutworm at Mack, Colo. 1944.

Material Used	Time of Application	Beans Injured per 100 Ft. Row	Computed Beans Injured, Lbs. per Acre	Per Cent Control	Yield Lbs. per Acre
Zinc arsenite	Aug. 18	67	7.29	91.5	653
Zinc arsenite	Aug. 27	76	8.27	90.3	859
DDT	Aug. 26	15	1.63	98.1	935
Check	—	779	84.86	—	1400
Copper arsenate	Aug. 18	230	25.05	70.5	1205
Copper arsenate	Aug. 27	168	18.30	78.5	1010
Cryolite	Aug. 18	625	71.56	15.7	1577
Cryolite	Aug. 27	579	63.07	25.7	1648

100 feet of row, 32 inches between rows = 0.06 acre.
100 average beans weighed 0.067 lb.

to 100 gallons of water was made. About 100 gallons of spray per acre per application was made, using a tractor drawn, 3 nozzles to a row, 4 row sprayer. The results are shown in Table 2.

This table does not include data on injury that occurred after the beans were shocked. A disease identified as red node[1] started on one side of the plots and spread across the field.

The spray tests were continued at Mack the following year using DDT .75 lb. DDT, 1.2 lbs; basic copper arsenate, 3 lbs.; and cryolite, 6 lbs. to 100 gallons of water. One application of spray was made the last of August using the same rate of application and spray equipment as the previous year. Each spray material was systematically replicated four times. The average results, based on samples of 50 feet of bean row from each plot are shown in table 3.

The spray materials in these tests gave the approximate degree of control as when used as dusts and reported in table 1. Plot C sprayed with basic copper arsenate contained 5 gallons of the DDT suspension used in spraying plot B. This amount of DDT almost doubled the percentage of control obtained with copper arsenate alone in plot D.

On October 1, 100 worms were placed under the shocks of unsprayed beans and under the shocks in each of the DDT plots sprayed on August 31. Seven days later 86 per cent of the worms were recovered from the shocks of the untreated beans, 24 per cent from the shocks of beans sprayed with .75 lb. DDT and 6 per cent from those that were sprayed with 1.2 lbs. DDT. This indicates that sufficient DDT remained on the sprayed bean vines to kill most of the worms under the shocks.

[1] Dr. Wm. Zaumeyer, Bureau of Plant Industry, U.S.D.A.

SUMMARY.—The cutworm that has been causing injury to pinto beans in five counties in Colorado has been identified as the larva of *Loxagrotis albicosta* (Sm.). A partial life history has been obtained so that approximate dates for applying insecticides effectually is known.

Of the insecticides tested, DDT gave the best control. The recommended control is 30 pounds per acre of a dust containing 3 per cent DDT in pyrophyllite. The dust is most effective when applied between August 15 and 30 as this is the approximate time the small cutworms start injuring the bean pods. In areas where bean rust is an additional problem 3 per cent DDT in dusting sulfur is recommended. In fields that have not been treated to control the small cutworms, the use of 3 per cent DDT dust under bean shocks will prevent injury

Table 3.—Results of spray tests for control of the bean cutworm, Mack, Colo. 1945.

Treatments	No. of Injured Beans, 50 Ft. Rows	Injured Beans Lbs. per A.	Per Cent Control	Yield per Acre Pounds
A. DDT .75 lbs.	4.25	.96	98.4	1225
B. DDT 1.2 lbs.	3.50	.74	98.7	1210
C. Copper arsenate 3.0 lbs.	53.00	12.11	82.2	1460
D. Copper arsenate 3.0 lbs.	144.50	33.04	44.1	1396
E. Cryolite 6 lbs.	209.70	47.91	31.0	1380
F. Check	274.50	69.80	—	1685

50 feet of row, 32 inches between rows = 0.03 acres.
100 average sized beans weighed .07 lb.

while in the shock and will reduce very materially the infestation the following year. While more information is needed before sprays can be recommended, wettable DDT, 0.75 pound in 100 gallons of water, is suggested.—6-21-48.

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Comparative Effectiveness of Variations in Spray Pressure, Rotenone Concentration, Sulfur Content, Diluents and Application Methods in Cattle Grub Control[1]

B. THOMAS SNIPES,[2] ROY S. COOPER[3] and S. W. CLARK[4]

Effective methods for control of cattle grubs have become an increasingly important experimental consideration since the introduction of high pressure spraying in 1942. Many authors have described and evaluated the economic importance of grubs and heel flies, and have conservatively estimated the annual loss to the cattle industry in the United States at one hundred million dollars.

Recommendations for grub control and subsequent heel fly reduction by treatment with preparations containing rotenone include hand application of washes and dusts, and power spraying with suspensions and emulsions. In 1943 and 1944 there was considerable diversity in recommended formulae and methods of treatment. Since information relative to effective control measures applicable for local conditions was extremely desirable, the authors decided to conduct some preliminary comparative control tests in Sheridan County, Wyoming, during the 1944 cattle grub season.

Induction of one of the authors into military service a few days after final grub mortality counts were made has prevented analysis and preparation of these data for publication until the present time. As at least some divergence in control recommendations still exists, results of the 1944 Wyoming tests are now presented for consideration.

Our purpose was to obtain an indication of possible differences in grub control effectiveness attributable to variations in power spraying pressures, rotenone concentrations of sprays, washes and dusts; the presence or absence of wettable sulfur in liquid preparations, various diluent-carriers for dust formulations, and methods of application.

Pressure under which power sprays are applied is considered to be an important variable in practical grub control. Workers in the U. S. Department of Agriculture (1944) reported more satisfactory kills at 400 to 410 pounds nozzle pressure than with 200 to 250 pounds.

The rotenone concentration of spray suspensions, usually given in terms of cube powder containing 5 per cent rotenone, is a second variable which exerts practical influence on success or partial failure of field grub control applications.

[1] Paid Paper.

[2] Technical Representative, U. S. Industrial Chemicals, Inc. (formerly State Entomologist, Wyoming Department of Agriculture).

[3] Sheridan County Pest Inspector (formerly Deputy State Entomologist, Wyoming Department of Agriculture).

[4] Manager, Agricultural Department, Texas Gulf Sulphur Company.

Laake *et al.* (1942), Snipes & Cooper (1942), Wells (1942) and Hixson (1946), have recommended a spray consisting of 5 pounds cube or derris powder (5 per cent rotenone) and 10 pounds wettable sulfur per 100 gallons of water. The U. S. Department of Agriculture (1944) recommends a suspension of 7.5 pounds cube or derris powder (5 per cent rotenone) to 100 gallons, and reports that at 400 pounds pressure, "sprays containing 5 per cent of rotenone from cube powder and wettable sulfur, or from cube powder and a wetting agent, were less effective and more expensive than the simple cube-powder suspension given above." Shull, *et al.*, Holm (1945) also recommend the above formula and state that sulfur or soap is unnecessary as a spray ingredient when the material is applied at 400 pounds pressure with adequate agitation, and indicate that the inclusion of sulfur may reduce the effectiveness of the treatment.

Hand wash preparations are commonly recommended at rotenone strengths many times more concentrated than spray suspensions.

The Bureau of Entomology & Plant Quarantine (1944) reports consistently satisfactory results from hand applications of 1 pint of a wash containing 12 ounces of 5 per cent rotenone powder with 4 ounces of granular laundry soap per gallon of water. Shull *et al.* (1945) recommends 1 pound of 5 per cent powder to 5 quarts. Hixson (1946) specifies 8 ounces of 5 per cent powder per gallon when used with 8 ounces wettable sulfur, or 12 ounces per gallon in combination with 4 ounces of neutral soap. Telford (1947) reports 90 to 100 per cent kill by hand application of a combination of linseed oil with 3 per cent and 8.6 per cent of 5 per cent rotenone extract.

Various workers have recommended certain carriers and rotenone concentrations for hand dust application, including 2.5 per cent rotenone with 325 mesh wettable sulfur (Laake *et al.* 1942), 1.67 per cent in pyrophyllite (Shull *et al.* 1945), 1 per cent rotenone with wettable sulfur, pyrophyllite or tripoli earth (Hixson, 1946), 1.67 per cent in double ground cream tripoli earth, volcanic ash, or pyrophyllite (U.S.D.A., 1944). Cuff reports average grub kills of 97.42 per cent with a cube-Tripoli earth dust (1.67 per cent rotenone) and observes that this preparation appears to be comparatively more effective against second instar larvae.

Munro, *et al.* (1947) reports 93 per cent control of cattle grubs, from a brushed in application of a commercial mixture containing 1.5 per cent rotenone, 2 per cent other derris resins, and 96.5 per cent talc, as compared with 92.8 per cent control from a similarly applied 2 per cent nicotine-sulfur mixture. Application of the dusts was made February 22 and repeated March 21. *Hypoderma lineatum* only was involved. Non-infested steers averaged nearly 43 lbs. greater gain per steer, during the wintering period, than the treated grubby steers.

Telford (1947), using rotenone at 1.5 per cent, obtained approximately 97 per cent grub control when calcium carbonate was used as the carrier, but grub mortality was only 33 per cent with this concentration of rotenone in combination with Fuller's earth.

EXPERIMENTAL MATERIALS.—The cattle used in these tests were Hereford yearlings, selected from a herd of 342 head. Experimental lots composed two feeding pens at the Sheridan Heights Ranch, owned by the Holly Sugar Corporation.[1] A total of 230 grubby yearlings were used in the actual applications. Grub populations were considered average and normal for this area during the early part of the season. Both the common species *Hypoderma lineatum* (DeVillers) and the northern grub *H. bovis* (DeGeer) are found in Wyoming, and all instars of both species were present in the backs of test animals.

The rotenone basis for all experimental preparations was South American cube root powder, originating from the Paranapura Cube Export Company, Ltd., of Iquitos, Peru. A composite sample of this material was analyzed by courtesy of the Bureau of Entomology and Plant Quarantine and was found to contain 8.3 per cent of rotenone and 22.4 per cent total extractives by the chloroform method. This analysis was in agreement with the label and invoice furnished by the distributor.

Wettable sulfur used in spray solutions,

[1] We wish to express our sincere appreciation to Mr. C. E. Cormany of the Holly Sugar Corporation, for his full cooperation not only in furnishing the experimental animals necessaryy for these tests, but also for providing us with chute and corral facilities, riders and ample additional labor for marking and handling the various test groups.

hand washes and dust preparations was 95 per cent pure, with at least 98 per cent, passage through a 325 mesh testing sieve. Dusting sulfur was of 92 per cent purity, 93 per cent 325 mesh. Both materials are products of the Southern Acid and Sulphur Company.

Power sprays were applied with an orchard sprayer capable of delivering and maintaining well in excess of 400 pounds pump pressure. This machine was equipped with an agitating mechanism adequate to maintain test preparations in suspension in the spray tank. A trigger shutoff gun, with No. 5 discharge disc was used for all power spray treatments.

EXPERIMENTAL PROCEDURE.—No attempt was made to measure grub populations in individual animals at the time of initial application. Examinations of representative yearlings and observations made during treatment indicated an average of approximately 15 grubs per head, with variations ranging from 5 to 50.

Experimental materials were applied on the afternoon of March 7, 1944. The day was sunny, but raw and chilly, with a 10-mile wind and an average temperature of 30° F. All applications of a similar control method were made by one operator, in an attempt to standardize treatments and reduce personal error.

Twenty-one experimental groups were included, with 10 to 12 animals in each lot. Animals with a given type of treatment were hair clipped with a distinctive mark to preserve their experimental identity during the necessary period.

Hand washes were applied in conformity with usual control recommendations (U.S.D.A., 1944), using 2-quart fruit jars with perforated lids. The material was scrubbed thoroughly into the backs of the animals by means of a stiff haired brush, at a controlled rate of 1 pint per head.

Dust mixtures were applied from calibrated quart fruit jars with perforated lids, at 3 ounces per animal, by sifting the material over the back and rubbing it vigorously into the hair with the hand (U.S.D.A., 1944).

Pumice carrier used in one sub-series was furnished by the Denver Fire Clay Company.[1]

Power spray applications were made as described by Snipes & Cooper (1942), the U.S.D.A. (1944) and Shull *et al.* (1945), using 2 quarts of suspension per head. Spraying was done from directly above the animal, with the nozzle no farther than 12 inches from the back, using a driving spray adjustment giving approximately 2 inch diameter coverage at a distance of 10 inches.

All treatments were made to animals confined in a narrow chute equipped with an adequate catwalk, allowing relatively easy access to the backs for power or hand application. Experimental applications were conducted in the following series.

Following treatment, all marked test animals were cut back into the feeding pens and held for subsequent examination. Previous experience had indicated appreciable difficulty in attempting to make accurate grub mortality and survival determinations in the relatively short period of 7 days. In order to obtain exact data as to dead and live grubs, a 14-day interval was allowed between applications and extractions.

This somewhat extended period has an apparent disadvantage in that it allows additional opportunity for first instar grubs to arrive in the backs of experimental animals. However, the purpose of these tests was primarily comparative, since previous checks have shown that the standard spray treatment gives a total kill of 93 to 100 per cent of all grubs present in the back at the time of application. Total mortality obtained in these tests may be somewhat lower than actual mortality of accessible grubs on date of treatment. New grub populations arriving in the back during the extraction interval should, however, be more or less constant for each experimental series and it is thought that comparison of results between different treatments on this basis can be expected to give valid indications of variations in effectiveness.

Grub extractions were made on March 21, 14 days subsequent to initial treatment. For reasons previously indicated, the scope of these tests was necessarily curtailed and each lot within experimental series was arbitrarily reduced to extractions from five animals. Such ani-

[1] Tripoli earth was furnished by the Independent Gravel Company of Joplin, Missouri, and was identified as Twice Ground Rose Tripoli, with a fineness classification of at least 98 per cent through a 200 mesh testing sieve. Pyrophyllite was supplied by Thompson-Hayward Chemical Company and was identified by the manufacturer as Pyrophyllite Talc.

mals were selected at random from the 10 to 12 animals which had received a common treatment. All the grubs, dead and alive, were extracted from each selected test animal, by squeezing or with the aid of artery forceps (Bishopp *et al.*, 1936). In so far as was allowable by the condition of extracted specimens, and within the limits of accurate identification, grubs were recorded not only as alive or dead, but were also determined to species and stage of larval development.

RESULTS.—Data included herein do not include individual lot records as to specific and instar mortality. In many cases, it was impossible to identify dead grubs either to species or to instars. Where such determinations were possible, there was no apparent difference in survival or mortality attributable to the species or stage of larval development concerned. Consequently, for convenience and brevity, results recorded to follow are given in total numbers and percentages of all instars of both species.

Table 1.—Cattle grub mortality as influenced by spraying pressure in power application. Standard formula of 5 lbs. 5 per cent cube (0.031 per cent rotenone and 0.082 per cent extractives) with 10 lbs. wettable sulfur per 100 gallons at 2 quarts per animal.

Series	No. of Animals	Pump Pressure Lbs. Sq. In.	Grub Mortality (14 Days) No. Alive	No. Dead	Total Grubs	Per Cent Control
A-1	5	200	14	38	52	73.1
A-2	5	250	18	49	65	75.4
A-3	5	300	7	28	35	80.0
A-4	5	350	10	82	92	89.1
A-5	5	400	2	78	80	97.5

Table 1 summarizes mortality and survival data from Series A, in which the rotenone, extractives and sulfur concentrations were held constant at the standard formula of 5 pounds 5 per cent rotenone powder and 10 pounds wettable sulfur per 100 gallons of water. Spraying pressure, as measured in terms of pounds per square inch in the piston pump, was varied in degrees of 50 pounds, from 200 to 400. A regular increase in grub kill appeared to coincide with increases in application pressure. The most effective grub control was obtained with a pump setting of 400 pounds.

Table 2 shows differences in total grub mortalities attributable to variations in the rotenone content of power sprays applied at 400 pounds pump pressure. A formula containing 10 pounds wettable sulfur per 100 gallons with no rotenone killed 14 out of a total of 92 grubs of all instars and species, or a mortality of approximately 15 per cent. This kill is not attributed to the sulfur in the spray, but is thought to have been produced by the mechanical force of the liquid applied under a driving pressure of 400 pounds.

With the wettable sulfur content constant at 10 lbs. per 100 gallons, and application pressure maintained at 400 pounds, cattle grub mortality increased as the rotenone concentration of the spray suspension was increased. One pound of 5 per cent rotenone powder (0.006 per cent ro-

Series A.—Variations in power spraying pressure, using a constant formula equivalent to 5 lbs. 5% cube powder and 10 lbs. wettable sulfur per 100 gallons of water (0.031% rotenone and 0.082% total extractives).

Lot No.	Pounds Pump Pressure
A-1	200 lbs.
A-2	250 lbs.
A-3	300 lbs.
A-4	350 lbs.
A-5	400 lbs.

Table 2.—Relationship of cattle grub mortality to rotenone concentration in high pressure sprays. All formulations applied at the rate of 2 quarts per head under 400 pounds pressure.

Series	No. of Animals	Formula (per 100 Gal.) 5% Cube	Per Cent Rotenone	Per Cent Extractives	Sulfur	Grub Mortality (14 Days) No. Alive	No. Dead	Total Grubs	Per Cent Control
C-2	5	0 Lb.	0.000	0.000	10 Lbs.	78	14	92	15.2
B-1	5	1	0.006	0.016	10	16	18	34	52.9
B-2	5	3	0.018	0.050	10	16	25	41	61.0
B-3	5	4	0.024	0.066	10	10	31	41	75.6
A-5	5	5	0.031	0.082	10	2	78	80	97.5
B-6	5	10	0.061	0.164	10	1	119	120	99.2

Series B.—Rotenone concentration of spray suspensions; variations in concentration of rotenone and total extractives, applied at 400 lbs. pump pressure. Wettable sulfur at 10 lbs. per 100 gallons was included in all formulations in this series.

Lot No.	Lbs. 5% Rotenone Powder Per 100 Gal.	Per Cent Rotenone	Per Cent Total Extractives
C-2	0	0.000	0.000
B-1	1	0.006	0.016
B-2	3	0.018	0.050
B-3	4	0.024	0.066
A-5	5	0.031	0.082
B-6	10	0.061	0.164

Series C.—Wettable sulfur concentration of spray suspensions (applications at 400 lbs. pump pressure).

Lot No.	Wettable Sulfur Per 100 Gallons	5% Cube Per 100 Gallons	Per Cent Rotenone	Per Cent Extractives
C-2	10 Lbs.	0 Lbs.	0.000	0.000
B-1	10	1	0.006	0.016
C-1	0	5	0.031	0.082
A-5	10	5	0.031	0.082

Series D.—Method of application of suspensions; hand washes at 1 pint per head, and power sprays at 4 pints under 400 lbs. pressure.

Lot No.	5% Cube Per 100 Gallons	Per Cent Rotenone	Per Cent Extractives	Wettable Sulfur Per 100 Gallons	Method
D-1	1 Lbs.	0.006	0.016	10 Lbs.	Wash
B-1	1	0.006	0.016	10	Spray
D-2	5	0.031	0.082	10	Wash
A-5	5	0.031	0.082	10	Spray
D-3	75	0.395	1.067	50	Wash[1]

[1] Corresponds to the recommended hand wash formula of 12 ounces 5% cube in a gallon of water.

Series D.*—Dust diluents for dry application; variations in rotenone concentration and in type of dust carrier, by hand application at 3 ounces per head.

Lot No.	Dilution Ratio	Per Cent Rotenone	Per Cent Extractives	Diluent	
D-9	1–9	0.50	1.35	Dusting Sulfur	90
D-6	1–4	1.00	2.72	Pyrophyllite	80
D-10	1–4	1.00	2.72	Dusting Sulfur	80
D-13	1–4	1.00	2.72	Wettable Sulfur	90
D-7	1–3	1.25	3.36	Pumice	75
D-14	1–3	1.25	3.36	Wettable Sulfur	75
D-5	1–3	1.25	3.36	Tripoli Earth	75

tenone and 0.016 per cent total extractives) produced slightly more than 50 per cent mortality, 3 pounds increased the kill to only 61 per cent, and 4 pounds resulted in approximately 75 per cent total mortality. However, the standard formula of 5 pounds 5 per cent cube powder (0.031 per cent rotenone and 0.082 per cent total extractives), with 10 pounds wettable sulfur, increased cattle grub kill to over 97 per cent of all species and instars. When the standard rotenone formula was doubled (10 pounds 5 per cent rotenone powder) total mortality was 99.2 per cent, but this difference is not significant within the experimental populations concerned in these tests.

Table 3 records differences in grub control resulting from inclusion or exclusion of wettable sulfur in rotenone spray suspensions. With no wettable sulfur in the formulation, a rotenone concentration of 0.031 per cent and 0.082 per cent total extractives (5 pounds 5 per cent rotenone powder), gave a grub mortality of slightly less than 80 per cent. When this rotenone concentration was used in combination with 10 pounds wettable sulfur per 100 gallons, however, total kills increased to over 97 per cent.

Table 4 compares the effectiveness of rotene-wettable sulfur suspensions, when used as a hand wash at 1 pint and as a power spray at 4 pints under 400 pounds pressure. Sulphur content of the first two suspensions in this series was maintained at 10 pounds per 100 gallons. One pound of 5 per cent cube powder (0.006 per cent rotenone and 0.016 per cent extractives) was relatively unsatisfactory as either a hand wash or a pressure spray, resulting in only 45.5 per cent and 52.9 per cent grub mortality, respectively.

Five pounds of cube powder (0.031 per cent rotenone) was much less effective as a wash (73.3 per cent kill) than as a spray (97.5 per cent). The formula commonly recommended for application by hand scrubbing, 12 ounces 5 per cent rotenone powder in a gallon of water corresponds to 75 pounds cube per 100 gallons. Under the conditions of these tests, this high concentration used as a hand wash at 1 pint per animal gave only 79 per cent total grub mortality when recorded 14 days after treatment. This was an increase of only 5.5 per cent control over that resulting from the application of a

Table 3.—Cattle grub mortality as related to wettable sulfur in high pressure sprays. Preparations applied at 2 quarts per head under 400 pounds pressure.

Series	No. of Animals	Formula (per 100 Gal.)				Grub Mortality (14 Days)			
		5% Cube	Per Cent Rotenone	Per Cent Extractives	Sulfur	No. Alive	No. Dead	Total Grubs	Per Cent Control
C-2	5	0 Lb.	0.000	0.000	10 Lbs.	78	14	92	15.2
B-1	5	1	0.006	0.016	10	16	18	34	52.9
C-1	5	5	0.031	0.082	0	16	62	78	79.5
A-5	5	5	0.031	0.082	10	2	78	80	97.5

Table 4.—Comparative effectiveness of hand washes and high pressure sprays in cattle grub control.

Series	No. of Animals	Formula (per 100 Gal.)			Method	Dosage	Grub Mortality (14 Days)			
		5% Cube	Per Cent Rotenone	Sulfur			No. Alive	No. Dead	Total Grubs	Per Cent Control
D-1	5	1 Lb.	0.016	10 Lbs.	Wash	1 pt.	42	35	77	45.5
B-1	5				Spray	4	16	18	34	52.9
D-2	5	5	0.031	10	Wash	1	12	33	45	73.3
A-5	5				Spray	4	2	78	80	97.5
D-3	5	75[1]	0.395	50	Wash	1	25	93	118	78.8

[1] Corresponds to the recommended hand wash formula of 12 ounces 5% rotenone powder to 1 gallon of water.

wash less than 0.67 per cent as concentrated, and was significantly less effective than this latter concentration when applied at 2 quarts per head as a power spray. An appreciable number of abscesses was evident in the backs of the more grubby experimental animals treated with the concentrated hand wash suspension. Only a few slight abscesses were noted in the test lots receiving other treatments.

Table 5 summarizes grub mortalities produced by hand application of 7 dust mixtures, at 3 ounces of material per head. In this form of treatment, a rotenone concentration of 0.50 per cent in 325 mesh dusting sulfur was evidently ineffective.

Rotenone content of 1.0 per cent in pyrophyllite, 325 mesh dusting sulfur and wettable sulfur, gave total mortalities of 50, 51.7 and 52.6 per cent respectively. There was no apparent difference in effectiveness attributable to the dust carrier used. At a content of 1.25 per cent, rotenone with pumice, wettable sulfur and double ground Tripoli earth produced kills of 50.9, 56.3 and 66.0 per cent. A larger number of test animals per lot, together with greater total grub populations might have indicated the Tripoli carrier as somewhat more effective.

In comparison with results obtained by power spraying with significantly less ac-

Table 5.—Hand dust applications in cattle grub control: influence of rotenone concentration and type of carrier on grub mortality (all treatments made at a calibrated dosage of 3 ounces per head).

Series	Animals	Formulation			Grub Mortality (14 Days)			
		Ratio	Per Cent Rotenone	Diluent	Alive	Dead	Total Grubs	Per Cent Control
D-9	5	1–9	0.50	90% Dusting Sulfur	81	10	91	11.0
D-6	5	1–4	1.00	80% Pyrophyllite	20	20	40	50.0
D-10	5	1–4	1.00	80% Dusting Sulfur	29	31	60	51.7
D-13	5	1–4	1.00	80% Wettable Sulfur	27	30	57	52.6
D-7	5	1–3	1.25	75% Pumice	29	30	59	50.9
D-14	5	1–3	1.25	75% Wettable Sulfur	38	49	87	56.3
D-5	5	1–3	1.25	75% Tripoli Earth	18	35	53	66.0

Table 6.—Comparison of grub mortalities and actual dosages of rotenone per head in methods of application.

METHOD	FORMULATION	APPLICATION PER HEAD		5% CUBE REQUIRED PER 100 HEAD	GRUB CONTROL
		Material	Ounces Rotenone		
Hand Wash	5-10-100	1 pt.	0.005	0.625 Lb.	73.3%
Power Spray	5-10-100	4 pt.	0.020	2.50	97.5%
Hand Dust	Cube-W. Sulfur (1-4)	3 oz.	0.030	3.75	52.6%
Hand Dust	Cube-Tripoli (1-4)	3 oz.	0.037	4.69	66.0%
Power Spray	10-10-100	4 pt.	0.040	5.00	99.2%
Hand Wash	12 oz.-1 Gal.	1 pt.	0.075	9.37	78.8%

tual rotenone per head, all hand dust formulations used in these tests were considered as relatively unsatisfactory. Present recommendations, not in effect at the time these experiments were conducted, specify a rotenone percentage of 1.67 per cent in hand dusts. The progressive mortalities obtained with 0.5, 1 and 1.25 per cent rotenone in our tests would indicate that control with a 1.67 per cent dust could be expected to approach or surpass 90 per cent.

The standard 5–10–100 suspension as a hand wash at 1 pint per head requires only 0.625 pound of 5 per cent cube powder for the treatment of 100 animals, but gave less than 75 per cent kill of grubs. When used as a power spray, however, this formulation gave excellent control and necessitates not more than 2.5 pounds of cube per hundred animals. The commonly recommended hand wash (12 ounces per gallon) uses almost four times as much rotenone and, in these tests, was significantly less effective.

SUMMARY AND CONCLUSIONS.—Comparative tests were conducted in Wyoming in March of 1944 to obtain an indication of possible differences in grub control effectiveness attributable to method of application, power spraying pressure, rotenone concentration, wettable sulfur content and type of dust diluent. Two hundred and thirty Hereford yearlings were treated and extractions were made at an interval of 14 days from 5 representative animals in each experimental lot. Twenty-one different applications were involved, with extractions of 1417 dead and live grubs from 121 treated animals.

Results of these tests are considered as preliminary and indicative, while conclusions allowable pertain to the conditions and conduct of this experiment.

All instars of both *Hypoderma lineatum* (DeVillers) and *H. bovis* (DeGeer) were represented in the backs of test animals, but there was no apparent difference in grub survival or mortality correlated with species or stage of larval development.

When a standard spray suspension was used at 2 quarts per head, grub kills increased with an increase in power spray pressure. A total mortality of 97.5 per cent of all species and instars was obtained at a pump gauge pressure of 400 pounds.

With a constant wettable sulfur content of 10 pounds per 100 gallons and a pump pressure of 400 pounds, grub mortalities were increased with an increase in rotenone content of the spray. A suspension containing 0.031 per cent rotenone (97.5 per cent kill) was significantly more effective than one with a concentration of 0.024 per cent (75.6 per cent mortality). Application of the 0.031 per cent rotenone suspension without wettable sulfur resulted in a reduction of 18 per cent in control effectiveness.

Rotenone-wettable sulfur suspensions of a given concentration were more effective as power sprays at 2 quarts per head than as hand washes scrubbed into the back at a dosage of 1 pint.

Dusts for hand treatment at 3 ounces per animal were less effective against cattle grubs than were power sprays, under the conditions of these tests. Dusts containing 1 per cent rotenone resulted in approximately 50 per cent mortality, while 1.25 per cent combinations gave slightly higher mortalities. There was no apparent significant difference between dusting sulfur, wettable sulfur, pyrophyllite and double ground Tripoli earth as dust diluents for hand treatment, al-

though the latter carrier gave some increase in total mortality.

For convenient and efficient treatment of medium or large herds of range or feeder cattle, proper power spraying at a minimum pump pressure of 400 pounds, at an approximate dosage of 2 quarts per head of a suspension composed of 5 pounds 5 per cent rotenone powder with 10 pounds wettable sulfur per 100 gallons of water, represents an economical, rapid and effective method of application which can be expected to kill well in excess of 90 per cent of all grubs accessible in the back at the time of treatment. 6-14-48.

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Effect on Livestock of Sprays and Dips Containing New Chlorinated Insecticides

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During the past few years DDT has been used extensively on livestock, particularly for the control of horn flies, *Siphona irritans* (L.), but other more recently developed insecticides have been less thoroughly tested. While DDT was being developed as a military insecticide, its toxicity to mammals received considerable study, and continued research by toxicologists gave indications of the relative toxicity of other chlorinated compounds. Those results, as reported to the Bureau of Entomology and Plant Quarantine, indicated that certain new compounds might not be so safe as DDT for application to livestock. Therefore, in the early spring of 1947 a series of tests were made at Kerrville, Texas, to help determine whether there was any risk of injuring livestock with certain formulations. During the following winter a second series was conducted, in which some of the tests were repeated and other insecticides were investigated.

GENERAL EXPERIMENTAL PROCEDURE. —The insecticides were applied at a concentration of 1.5 per cent (by weight) of the technical material, as sprays to cattle and hogs and as dips to sheep and goats, and were sponged onto horses. Whatever the method of treatment the animals were thoroughly wetted to the skin. Applications were repeated at 4-day intervals until eight treatments had been made.

The test animals were held in a 100-acre pasture during the period of the treatments and for an additional 30-day observation period following the eighth treatment. Cowboys rode in the pasture

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almost daily for inspections and brought to the veterinarian any animals that seemed sick. As the pasture was somewhat brushy, not every animal was observed on such inspections. Thorough examinations were made on the days when the animals were rounded up for treatment or weighing. The animals were weighed at the beginning of the test, after the eighth treatment, and finally 30 days after the last treatment.

FIRST SERIES OF TESTS.[2]—The materials involved in the first series of tests were the following commercially formulated insecticides: Chlordan wettable powder, chlordan emulsion concentrate, benzene hexachloride (10 per cent gamma isomer) wettable powder, and chlorinated camphene wettable powder. Each insecticide was applied to 5 Angora goats, 5 Delaine sheep, 2 Hereford heifers, and 1 horse (cow-pony type). A similar group of animals treated only with water served as controls. All the animals were healthy and in good range condition at the beginning of the test.

With the exception of the sheep and goats receiving chlordan treatment, all animals survived the experiment, apparently in good health. Weight gains varied within all groups; so no conclusive observations could be made from them. In other words, chlorinated camphene and benzene hexachloride showed no toxic effect upon any of the animals, and chlordan gave no visible evidence of injury to the horses and cattle used.

One yearling lamb dipped in a suspension of chlordan wettable powder was found dead 4 days after the third dipping. A second lamb was found dead 3 days after the fourth dipping. One yearling goat was found affected 4 days after the fifth dipping and died the next day. Another kid showed symptoms 5 days after the eighth dipping and died 7 days later.

All five sheep dipped in chlordan emulsion died, the first displaying symptoms 4 days after the fifth dipping and dying 3 days later. A second sheep was found affected 2 days after the sixth dipping and died 12 days later. The third and fourth sheep were found dead 4 days after the sixth dipping. The fifth sheep went into convulsions when attempts were made to make the eighth application and died about an hour later.

Two goats dipped in chlordan emulsion died. The first, a yearling kid, showed symptoms 4 days after the fifth application and died 8 days after that application. The second goat, a mature animal, was found dead the day after the seventh application.

The symptoms and lesions of chlordan poisoning have been described by Radeleff (1948). They may be summarized in the main as follows: Blindness, partial to complete, along with disturbances of the ability to walk were noted first. Next, the animals suffered convulsive attacks and were unable to arise. Gritting of the teeth and agonal crying were characteristic predeath symptoms. Death was always agonal and occurred from 1 to 12 days after symptoms were first noted. No animals recovered, once symptoms were noted. Lesions found on autopsy were usually swelling of the liver, some kidney involvements, and subserosal hemorrhage of the intestines and heart. Micropathology usually consisted of fatty changes in the liver or kidneys or both.

Ray L. Cuff, of the National Live Stock Loss Prevention Board, made similar treatments at the request of the Bureau using cattle, sheep, and horses held in barns. He noted no injury from the chlorinated camphene or benzene hexachloride, but reported that chlordan, in addition to killing some of the sheep, killed one of the two cattle treated with the wettable powder and one of those treated with the emulsion.

SECOND SERIES OF TESTS.—In the second series of tests the insecticides used were chlordan, benzene hexachloride (12 per cent gamma isomer), chlorinated camphene, the methoxy analog of DDT, 2,2, bis-(*p*-chlorophenyl)-1,1, dichloroethane and DDT. All these materials were tested as emulsion concentrates, and chlordan, chlorinated camphene, and DDT also as wettable powders. The wettable powders were commercial formulations. The emulsion concentrates were prepared by dissolving 25 parts of the technical insecticide in 65 parts of xylene and adding 10 parts of an aralkyl polyether alcohol[3] as an emulsifying agent. Solution of benzene hexachloride in the

[2] Charles L. Smith and O. G. Babcock assisted with these tests.

[3] *Triton X-100.*

xylene was incomplete, but it is believed that all of the gamma isomer was dissolved.

Each formulation, including a control treatment of plain water,with the exception of chlordan, which was used only on sheep and hogs, was applied to 5 sheep, 5 goats, 2 cattle, 2 hogs, and 1 horse. Time intervals and methods were the same as for the first series of tests.

It was interesting to note that the xylene concentration of 3.6 per cent in the final mixed spray or dip caused the animals to react abruptly. Sheep were paralyzed within 3 minutes of dipping, most of them becoming anesthetized. Recovery was complete in 30 minutes, with no apparent after-effects. Cattle sprayed with xylene emulsions evidenced intense irritation by kicking and butting in a frenzied manner. Horses showed discomfort by running. One developed colic, which lasted several hours. All horses showed flakiness of the skin at the end of the test as a result of the irritation. Goats and hogs seemed not to be affected.

All animals survived the test in apparently good health, except one sheep which died of a diffuse actinomycosis of the skin. The death was in no way attributable to insecticide activity. Weight gains and losses varied from group to group and within each group; so no definite conclusions could be drawn from weight records.

DISCUSSION.—In interpreting the results outlined above, consideration should be given to the extreme severity of the tests. The insecticide concentration of 1.5 per cent might well be used in practice for the control of very resistant pests, such as ticks, or to provide for a long-lasting residual effect. However, the 4-day interval between treatments was much less than would be followed in practical use, and the number of treatments was greater than one would expect to apply in a single season. The severity of the tests was deliberate, because they could be made with only a small number of animals. It was assumed that, if negative results were obtained, the insecticides could be used on large numbers of animals for practical field tests, but that if any insecticide showed toxicity it should be used with caution in the field work. Thus, the tests were not so much for toxicological studies as a search for information as a guide to subsequent field tests.

The difference in results with chlordan in the two series is difficult to explain. Chlordan from different commercial sources was used. The commercial chlordan emulsion concentrate was found to deteriorate in storage so that it would no longer mix properly with water. A sample was returned to the manufacturer, and that company reported finding relatively large amounts of hydrochloric acid in the sample, which indicated that the chlordan had decomposed. The second series of tests were made with chlordan of different manufacture. The same company formulated the wettable powder, and the emulsion concentrate was made at the laboratory. The chlordan used for both formulations had been recently synthesized. The fact that the two new chlordan preparations caused no apparent injury to sheep indicated the possibility that earlier losses may have been due to decomposition of the material in storage.

The second series of tests were made in November and December. Beginning in January, chlordan wettable powder from the same container that was used in those tests was applied to 10 Hereford cows as a part of a test described in the next section. The fact that the material caused the death of three of the animals proved its toxicity.

It is questionable whether the powder, stored in an unheated building in winter, had decomposed sufficiently to become toxic. It may be that at the time of testing against sheep in the second series, the powder was not so toxic as the other powder, which caused the death of two of five sheep in the first series.

OBSERVATIONS INCIDENTAL TO FIELD TESTS OF INSECTICIDES.—During the past year various members of the Kerrville laboratory have applied the new insecticides in connection with their research on control of livestock pests. Some of those treatments that are of toxicological interest are summarized below.

A wettable powder of gamma benzene hexachloride was sprayed by W. C. McDuffie on three cows at each of the following concentrations: 1.5, 0.75, and 0.25 per cent. All three cows treated with the highest concentration died within 24 hours. Two of three cows were affected by the intermediate concentration, one died and one recovered. The 0.25 per cent concentration caused no visible effects.

Using gamma benzene hexachloride at a concentration of 0.5 per cent, G. W. Eddy and O. H. Graham dipped sheep that were in long fleece, five in a suspension of wettable powder and five in an emulsion. Nine of the sheep appeared unaffected, and one animal died 107 days after dipping. This sheep had been treated with the emulsion and 7 days later had received an application of a paste containing about 2 grams of gamma benzene hexachloride over the surface of a small screwworm-infested wound. The wound healed normally in 30 days and the animal seemed unaffected when released from the test, but 97 days after the original treatment exhibited symptoms of neurological poisoning.

A chlordan wettable powder in a 2-per cent suspension was thoroughly sprayed over the entire bodies of 10 cattle at 2-week intervals, as a phase of a test conducted by O. H. Graham. Ten days after the fourth spraying one heifer died of chlordan poisoning; on the twelfth day another heifer and a cow died from the same cause. Other groups of cattle were similarly treated with suspensions made with wettable powders of DDT 2,2-bis-(*p*-chlorophenyl)-1,-1-dichloroethane benzene hexachloride (12 per cent gamma isomer), methoxy analog of DDT, and chlorinated camphene. These cattle were subjected to eight sprayings and no apparent injury has resulted.

The above-mentioned cases represent the only insecticide poisoning observed in field work at the Kerrville laboratory.

Benzene hexachloride (technical, containing 10 to 12 per cent of gamma isomer) has been tested on a wide scale. The heaviest application was a concentration of 2.5 per cent in which 10 sheep were dipped without harm.

Many tests have been made with chlorinated camphene. Nine sheep suffered no injury from being dipped once in 2.5 per cent of this material, the highest concentration used.

Chlordan was applied four times during the summer of 1947 to 13 dairy cows as a 0.5-per cent suspension. Four sheep were dipped once in a 2.5-per cent suspension without evidence of injury.

SUMMARY.—DDT, 2,2,bis-(*p*-chlorophenyl)-1,-1-dichloroethane the methoxy analog of DDT, benzene hexachloride (10 to 12 per cent gamma isomer), chlorinated camphene, and chlordan have been applied to cattle, sheep, goats, hogs, and horses in attempts to induce insecticide poisoning.

The materials were used as emulsions and as suspensions of wettable powders at concentrations of 1.5 per cent of the technical material, applied as sprays and dips. Two series of tests were made, the treatments being applied eight times at 4-day intervals. Observations were continued for at least 30 days after the last treatment.

In addition to those tests, the insecticides have been widely used, sometimes at high concentrations, in the field work of the Kerrville, Tex., laboratory.

No apparent injury has been noted from treatment with DDT, the methoxy analog of DDT, technical benzene hexachloride, dichlorodiphenyldichloroethane or chlorinated camphene.

Some animals have been killed by very heavy chlordan applications while others in the same treatment groups suffered no apparent harm. The principal symptoms of chlordan poisoning were neurological while the chief pathological conditions were liver damage and subserosal hemorrhages. No animals recovered, once they were visibly affected by chlordan.

A wettable powder of gamma benzene hexachloride, applied once as a spray to groups of three cows, caused no injury at 0.25 per cent concentration, killed one and affected another at 0.75 per cent, and killed all three at 1.5 per cent.—5-11-48.

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SCIENTIFIC NOTES

The Swarming Season for Honey Bees in Manitoba

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Every efficient beekeeper tries to keep every colony in his apiary from swarming. In order to prevent swarming, it is essential for him to know when swarms are likely to issue from his colonies. For over twenty years certain beekeepers in Manitoba have each kept an average colony of honey bees on a set of platform scales and have recorded the daily changes in the weight of their scale colonies. On the printed form on which the records were kept, there is a space to record the date when any swarm emerged from any colony. Although no doubt many swarms issued unobserved from time to time, many of these beekeepers recorded dates when they did observe swarming and these dates have been used to establish the swarming season in Manitoba. From 1926 to 1945 some 1087 such dates were recorded and were used as a basis for figure 1.

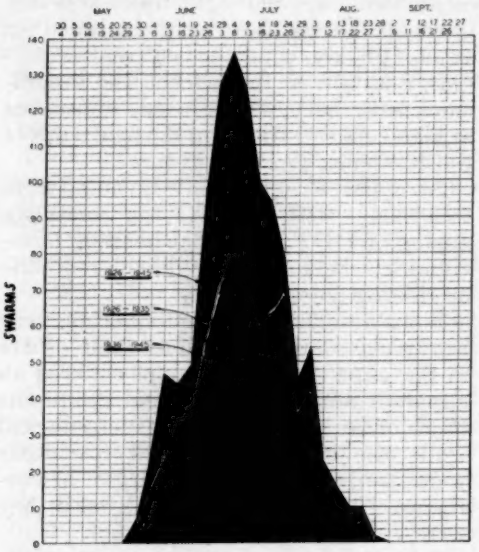

FIG. 1.—The continuous white line shows the total swarms recorded for each five day interval during five months of each summer for the ten year period, 1926 to 1935, while the broken white line indicates the total swarms similarly for the ten years, 1936 to 1945. The silhouette portion of the figure shows the total number of swarms which emerged for similar five day periods for the twenty years 1926 to 1945.

DISCUSSION.—The continuous white line in figure 1 shows the total swarms for each 5-day interval during 5 months of each summer for the 10 year period 1926 to 1935, while the broken white line shows the total swarms similarly for the 10 years, 1936 to 1945. The silhouette part of the figure indicates the total swarms which emerged for similar 5-day periods for the 20 years 1926 to 1945. For example for the 5-day period, June 9 to 13, 47 swarms were seen over the 20 years noted above.

An examination of the silhouette portion of the figure shows that swarms began to issue about June 1 and increased in number for each five day period following, with one exception, until the peak of the swarming season was reached during the five day period, July 4 to 8. From that time on, swarming fell off steadily for each five-day period, with two exceptions, until the end of August. Swarming was confined to the months of June, July and August. Just over 62 per cent of the total swarms emerged during the thirty day period from June 24 to July 23. Of the total swarms recorded, 29 per cent emerged in June, 59 per cent emerged in July and 12 per cent emerged in August.

For the 10-year period, 1926–35, figure 1, the peak of the swarming season was reached during July 4 to 8 also. For the second ten year period 1936–1945 the peak was reached 5 days earlier, namely, during the period June 29 to July 3. Swarming then fell off rapidly during July and very few swarms were recorded during August. It seems therefore that the peak of the swarming season has advanced slightly and that relatively fewer swarms emerge during the latter part of the season. The swarming period in Manitoba is continuous.

Mitchener (1947) has shown that the honey flow in Manitoba during the ten year period, 1935 to 1944, reached its peak approximately July 19. This is about two weeks after the swarming peak has been reached. It is of interest to observe that in the same paper the graphs show that the main Manitoba honey flow begins in earnest about the middle of June which is approximately two weeks later than the beginning of the swarming season which, as we have seen, is around June 1.

Swarm control must be undertaken previous to June 1 and continued at least until the middle of July in Manitoba. The progress of each colony in May will determine the time for the first swarm prevention measures. If packages are to become strong for the early part of the honey flow around the end of the third week in June, they should be installed in the Manitoba apiary before the middle of April. Such packages are not likely to make preparations for swarming until well along in June although seasons and individual colonies vary.

SUMMARY.—(1) This paper is based upon the recorded dates when 1087 swarms issued from Manitoba apiaries during a 20-year period, 1926 to 1945.

(2) The swarming season for honey bees in Manitoba begins around June 1, reaches its peak during the first week of July then subsides and practically comes to an end by the middle of August.

(3) The beginning of the swarming season precedes the beginning of the main honey flow by about two weeks. The peak of the swarming season is reached also about two weeks before the peak of the honey flow. The decline of the swarming season corresponds approximately with the decline of the honey flow during the last half of July and the first half of August.

ACKNOWLEDGMENTS.—To the many beekeepers who have from time to time over a period of twenty years kept a record of the dates when swarms issued from their apiaries, the author is indebted for the basic information given in this paper.—4-25-48.

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Vacuum Dusting of Insects and Plants

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The application of predetermined amounts of insecticides or fungicides on insects and plants has been accomplished in many ways. The techniques vary widely among workers. Some of these techniques have proven very useful in making analysis of the biological properties of chemical unknowns. No attempt is made in this paper to evaluate the merits of these methods.

In the testing of chemicals, either liquids or solids, at room temperature two general methods have been employed. Chemicals soluble in organic solvents may be sprayed directly in the solvent or the chemical and solvent emulsified and sprayed with a third carrier, usually water. In most cases the actual formulation may often be as important as the inherent toxicity of the chemical unknown. Spraying of such mixtures is further subject to errors due to differences in plants, insects, cages, temperature and humidity. The amount of toxicant deposited varies within wide limits. Many replicated tests are often required to determine the correct properties of a chemical.

By a second method of preparation the same class of chemicals can be formulated into dusts and applied as dusts, Chemicals that are sufficiently hard to permit grinding can be formulated by grinding directly with an inert carrier. Chemicals that are either liquid or waxy may be dissolved in a volatile organic solvent, mixed with a carrier or extender and the volatile solvent removed by evaporation. In either case the final preparation consists of a known percentage of chemical impregnated on to or dispersed among the particles of a carrier or extender.

Workers have generally considered sprays to be a more usable method of testing than dusting. For all general purposes this was probably true. Some laboratories, however, have developed dust towers in

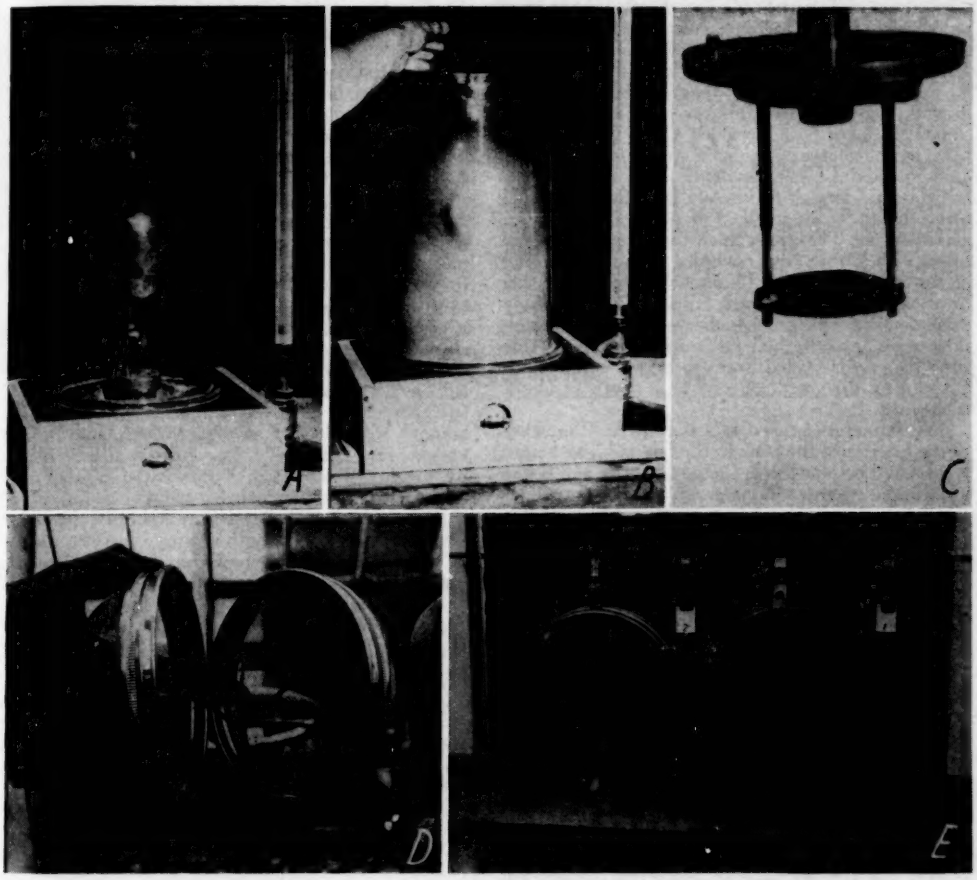

FIG 1. A—Bean plant within vacuum bell jar in position for dusting. B—Dust cloud within bell jar the instant the rubber stopper is removed. (Note plastic protective shield in working position.) C—Detail of metal dusting unit. D—Cage for confining untreated insects to a dusted plant. E—Holding cage for dusted milkweed bug nymphs or adults.

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[3] Howard W. Smith, Research Fellow, Crop Protection Institute, Durham, N. H.

which they have been able to obtain very reliable data from dusts. The development of these towers has greatly improved laboratory dusting techniques. However, the methods are slow, requiring a definite time interval for the dust to settle onto the plant. Since the settling is downward the upper surfaces of the plant are coated heavier than the lower surfaces.

Several types of dusting chambers were built to apply measured amounts of dust to plants. None were too successful until at the suggestion of Dr. W. C. O'Kane the dusting chamber was evacuated. Following this lead the Crop Protection Institute in July 1946 perfected a method of applying dusts to plants or insects quickly and in an extremely uniform manner. The method is so simple that it may be readily adapted to routine laboratory screening techniques.

The apparatus consists of an open top glass bell jar mounted on a properly designed steel base. The base is made of 0.375 inch sheet steel 12 inches square. Into the base is welded a 0.25 inch vacuum port. In the center is welded a steel cup 4 inches in diameter and 4 inches in depth. This cup receives the clay pot that supports the growing test plant. Only the plant stem and foliage extend into the glass bell jar. The upper open top of the bell jar is fitted with a brass unit covering the entire opening of the jar (Fig. 1-C). Through the center of this brass unit is fitted a brass tube 0.5 inch in inside diameter, extending 0.5 inch above and 0.75 inch downward into the bell jar. Supported below this tube by two threaded brass rods is a copper disc 1.5 inch in diameter concave to a depth of about 0.125 inch.

The diameter of this disc is slightly less than that of the interior of the neck in the bell jar. The height is adjusted to just below the neck of the bell jar at a position where 0.25 inch of clearance extends around the disc.

On the bottom of the unit is attached a 0.125 inch sponge rubber gasket that seals rapidly during evacuation. A similar gasket seals the base of the glass bell jar.

In working with glass equipment under vacuum a certain element of danger exists. To protect the operator against possible failure the bell jar is surrounded by a heavy plastic cylinder (Figure 1, B.).

The amount of vacuum used is measured on an especially designed barometer. It is made by inserting within a larger glass tube sealed at one end a smaller glass tube with 0.187 inch inside diameter. The smaller tube dips into a well of mercury exposed to atmospheric pressures. The connection between the two tubes is so sealed that by evacuating the larger tube through a side connection, mercury climbs the smaller tube to about 29 inches. The smaller tube extends 33 inches above the mercury surface and does not overflow. If too small a tube is used in the barometer the mercury will separate and not return to the well during routine operations.

The standard laboratory vacuum pump is protected from contamination by dust with a glass-wool filter placed between the bell jar and the pump. An occasional cleaning of the filter may be necessary during continuous operation. The operation can be speeded up by pumping against a 10 gallon vacuum reserve tank. A single brass valve is placed in the vacuum line between the pump and the apparatus. When this valve is closed the pump works against the reserve tank. Opening of the valve will evacuate the bell jar equipment in about 30 seconds.

The apparatus will work under a wide range of vacuums. For this equipment all testing is done at 10 inches less pressure than barometric pressure of 29.5 inches, working pressure 19.5 inches of mercury.

Plants are dusted by placing the plotted plant in the apparatus base and setting the bell jar in position. A weighed amount of dust (0.2 gram) is placed on the copper pan and the metal unit is fitted on the bell jar. A smooth rubber stopper is placed on top of the tube extending through the cap (Fig. 1, A). The valve is opened to draw the desired vacuum and then closed. The stopper is then removed. Atmospheric pressure forces air into the jar until equilibrium has been regained. As the air enters the apparatus it picks up the dust from the pan and deposits it almost instantly on all parts of the plant (Fig. 1, B).

In dusting insects without plants the insects are placed in hemispherical wire cages. The cage is placed within the apparatus and treated identically as with plant techniques. After treatments the test insects are transferred to clean cages or untreated plants for further observation (Fig. 1, D & E).

The collection of stray dust and the removal of dust from the bell jar between tests was accomplished by a separate dust collecting unit. At the side of the testing apparatus was arranged a tight box with an open top. A standard vacuum sweeper was attached to this box through a port in the side. In practice after each test run the bell jar is set over this box and is swept clean by air going to the sweeper. Excess dust from the base of the apparatus also is swept into the vacuum sweeper.

Calibration of the apparatus was done with DDT cut back with pyrophyllite. A load of 0.2 gram per test gave the most consistent results and this amount was adopted as a standard. After testing varying ratios of DDT to pyrophyllite a ratio of 5% by weight was adopted as standard for DDT and other unknown chemicals.

Chemicals that gave performance at this level were cut back by one half with pyrophyllite until a 50 per cent control level was obtained, for example 0.2 gram load at 5.0, 2.5, 1.25, 0.625 per cent actual chemical with pyrophyllite. The above treatment was found satisfactory for biological evaluation of the organic insecticides now in use. The method may have an equal value for fungicide studies along similar lines of investigation.—1-10-48.

An Improved Cage for Work with Small Insects

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The cage devised and illustrated by Munger (1942) is especially suitable for work with small insects on detached leaves. The leaves remain in good condition for a surprisingly long time. However, the usual cage is constructed of glass having rough, chipped, oval cells of rather irregular sizes.

This cage was modified by the writer, by using sheet plastic[2] of 3 mm. thickness cut to the size of the wooden block, made of water-proof plywood, and by the use of a smoothly cut circular opening of 31 mm. diameter as the cell. A second plastic sheet was used as a cover. Such a cage has all the advantages claimed by Munger for the original cage, and certain additional features as well. It is easily and readily constructed. The holes are made with an

[1] The helpful suggestions of Mr. James K. Holloway are gratefully acknowledged.

[2] *Plexiglass* or *Lucite*.

electric drill. The cells are smooth-edged and of uniform size and shape. The material is non-breakable. The smoothness of the edges promotes clarity of vision through the cover without the necessity of sealing the edges with paraffin. The cell is a good size for bean, pear, or apple leaves.

Two layers of desk blotter paper were used beneath a gauze pad on which the leaves rest. Bean leaflets, a rather tender type of foliage, stood up so well for 3 and 4 weeks that the midribs had rooted and the roots had grown through the pads in many cases at the end of the tests.

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Additional Host Records for the Scale *Parlatoria theae* in California

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In the course of surveys for new pests undertaken in conjunction with the California Bureau of Entomology and Plant Quarantine as part of the state-wide survey program outlined by H. M. Armitage (1948), a heavy infestation of the scale insect, *Parlatoria theae* Cockerell, was discovered. About 50 trees and shrubs in one commercial nursery and two residential premises were involved in the city of San Diego.

This infestation under sub-tropical conditions gave the scale opportunity to attack hosts previously unrecorded. (McKenzie 1945; Morrison 1948). These include avocado (Lauraceae), *Bauhinia* (Leguminosae) and apricot, loquat and *Pyracantha* (Rosaceae). Previously recorded hosts also found infested included rose, plum and *Pyrus* (a flowering form).

Other recorded hosts which were exposed to infestation but on which no scale could be found included citrus (lemon and sweet oranges), *Hibiscus* and *Poinsettia*.

Extensive measures, which include cyanide fumigation and oil sprays, have been undertaken to eradicate this incipient infestation of a potentially serious oriental species.—4-30-48.

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Toxicity of Parathion to Mosquitoes[1]

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Parathion the latest of the new toxicants to appear on the insecticide horizon, was developed in Germany during the last war and is now manufactured by the American Cyanamid Company. It is an ester of thiophosphoric acid, termed o,o-diethyl o-p-nitro pheny-thiophosphate, of the following chemical formula: $SP(OC_2H_5)_2\ C_6H_4PNO_2$. It is very slightly soluble in water but dissolves in many organic solvents.

MATERIALS AND METHODS.—Parathion in the form of (1) colloidal dilutions in water, (2) oil emulsions and (3) dusts were tested on third instar larvae and on pupae of *Aëdes aegypti*.

Table 1.—Comparative toxicity of parathion and DDT to mosquito larvae and pupae.

METHOD OF APPLICATION	LARVAL MORTALITY IN 48 HOURS		PUPAL MORTALITY IN 24 HOURS	
	50%	*100%*	*50%*	*100%*
1. Water dilutions *Parathion. PPM.*	0.003	0.005	0.25	1.0
2. Surface Application in oil *Parathion. Pounds per acre*	0.0025	0.006	0.06	0.20
3. Surface Application in dust *Parathion. Pounds per acre*	0.001	0.005	0.10	—
4. DDT—PPM	0.014	0.05	25.0	230.0

For the water dilutions, 1 cc. of ethanol containing various concentrations of the toxicant was stirred in 200 cc. of distilled water in a 250 cc. beaker in which larvae or pupae had been previously placed. In preparing the emulsions the desired concentrations of parathion were dissolved in No. 2 fuel oil containing 1 per cent emulsifer.[2] The emulsions were diluted 1 to 3 with water prior to application. The required volume of oil was deposited on the water surface from a pipette calibrated so that a drop was equivalent to 1 quart of actual oil per acre. The oil film was spread by the aid of a stirring rod to cover the entire water surface. The tests with emulsions and dusts were made in porcelain dishes containing 500 cc. of water, giving an approximate surface area of 0.27 sq. ft. About 150 larvae and 100 pupae were used with each concentration of the toxicant for all the materials tested.

The dusts were prepared by mixing various concentrations of parathion in pyrophyllite by pestle and mortar. The required quantities of dusts were

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, Department of Entomology.

[2] *Triton X-100.*

weighed and evenly deposited on the water surface in the dishes. The concentrations of parathion were calculated in parts per million for water dilutions and in pounds per acre for emulsions and dusts.

RESULTS.—The data from all the tests are summarized in table 1 on the basis of 50 per cent and 100 per cent mortalities, in comparison with DDT,—taken from a previous investigation.[1]

The table reveals the following information concerning the toxic properties of parathion. On larvae, 100 per cent mortality occurred with 0.005 PPM in water dilutions and with about 0.005 pound per acre in surface applications of either dust or emulsions. On pupae, 100 per cent kill resulted from 1 PPM parathion in water dilutions and about 0.2 pound per acre in oil emulsions. The highest pupal mortality from dust treatments was only 80 per cent at 0.5 pound parathion per acre. From these results it appears that parathion possesses higher toxicity to larvae and pupae than DDT. However, further investigations will have to be conducted with this new toxicant under field conditions on several species of mosquitoes, as well as on its injurious effects to warm blooded animals officially determined, before its use in mosquito control work can be evaluated.

SUMMARY.—Laboratory tests were conducted with parathion as water dilutions, oil emulsions and dusts on larvae and pupae of *Aëdes aegypti*. The results indicate that parathion is several times as toxic to mosquito larvae and pupae as is DDT.

A Technique for Translocation of DDT in Plants

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During the past year the writer has been engaged in a study of the possible physiological effect of the feeding of the 2-spotted mite, *Tetranychus bimaculatus*, on leaves treated with DDT. Numerous instances of mite build-up associated with DDT treatments suggested a study to ascertain if these are the result of reduced or eliminated predator action, or of some increase in fecundity (perhaps due to greater host favorableness or lowered resistance) coincidental with, but not necessarily related to, predator destruction, or both.

The bean plant was utilized in the preliminary work, and, although no increase in fecundity of this mite was shown in these tests, the technique developed is one which may well prove useful in this and other lines of research. It was desired to get DDT into the inner tissues of bean leaves without any surface treatment whatever. A review of research on the movement of plant hormone materials or sub-products through plant tissues revealed two solvents and several methods which could be tried for the movement of DDT in the translocation stream of plants. Mitchell and Hamner (1944) used polyethylene glycols[3] as carriers for growth-regulating substances. Beal (1944) used both a polyethylene glycol and lanolin as carriers, applying the regulators as "pellets" dissolved in the respective carriers Felber (1947) soaked threads in the materials and threaded them through the plant tissues.

Three methods were used to get DDT into the upper leaves of string beans. 1) Pellets of half DDT and half polyethylene glycol were applied to each primary leaf. 2) Pellets of half DDT and half lanolin were similarly applied. 3) A solution of DDT in the polyethylene glycol was dispersed in water by melting 10 grams of DDT in 35 grams of the wax and adding, while stirring, to 200 cc. of water. This dispersion was filtered through ordinary filter paper, but the filtrate retained its milky color. The milkiness clears and settles after a week or two—more rapidly under effects of heat and sunlight. Cotton twine wicks were threaded through the stems of the plants at ground level from a 5 cc. vial of the material. The vials were refilled once after 1 week.

The presence of DDT in the upper leaves was determined in two ways. 1) When the plants were 4 weeks of age the top 3 compound leaves were removed and analyzed for DDT content. A total of 162 leaflets were used for each treatment. 2) *Scymnus binaevatus*, a DDT-sensitive coccinellid, was used in biological assay tests. Adults of *Scymnus* were exposed in petri dishes carrying a residue of alcohol-soaked and macerated upper leaves from the wick-fed plants. The results of these tests are shown in tables 1 and 2.

Table 1.—DDT content of upper leaves of bean plants which received DDT only at lower points.

METHOD OF APPLICATION	DDT PARTS PER MILLION
DDT: Polyethylene glycol pellets on primary leaves	1.8
DDT: Lanolin pellets on primary leaves	4.5
DDT: Polyethylene glycol water dispersion through wick at base of stem	11.3

Table 2.—Mortality of *Scymnus binaevatus* exposed in dishes treated with macerated upper leaves of bean plants receiving DDT by wick at ground level.

	NUMBER TREATED	NUMBER DEAD IN 12 DAYS	PER CENT DEAD
Treated Dish	30	26	87
Control Dish	30	4	13

Since the wick method gave by far the highest DDT content, it is obvious that the DDT travelled through the translocation stream, and was not a result of contamination. The possibility of any external contamination was at a very minimum with this method. The results of table 1 prove the movement of DDT into the upper leaves, and those of table 2 that the DDT content reached was sufficient under these conditions to be lethal to a of coccinellid.

An interesting observation was the occurrence of leaf tip burn resulting from the treatments, particularly noticeable on plants held under greater shade (in the laboratory as compared to the greenhouse) and treated by the wick method.—6-8-48.

[1] Ginsburg, J. M. 1947. Tests with Toxicants in Comparison with DDT, on Mosquito larvae and fish. Proceed. 34th Annual Meeting, N. J. Mosq. Exter. Assoc., pp. 56–60.

[2] The generous assistance of Mr. O. H. Fullmer in carrying out the chemical analyses is gratefully acknowledged.

[3] *Carbowax* and others.

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Experiments with DDT for Control of the Potato Leafhopper on Apple Nursery Stock[1]

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The potato leafhopper, *Empoasca fabae* Harris, as it is commonly known, is often a serious pest of apples in the nursery planting. Both nymphs and adults feed on the tender terminal growth, cause the leaves to curl and produce definite stunting which affects the quality of the nursery stock (Fig. 1). Lathrop (1918) reported serious injury to foliage of apples in nursery plantings and young orchards.

FIG. 1.—Injury to 1-year old apple tree by leafhopper. Note cessation of growth of terminal bud (center); lateral buds continue to grow normally (lert and right).

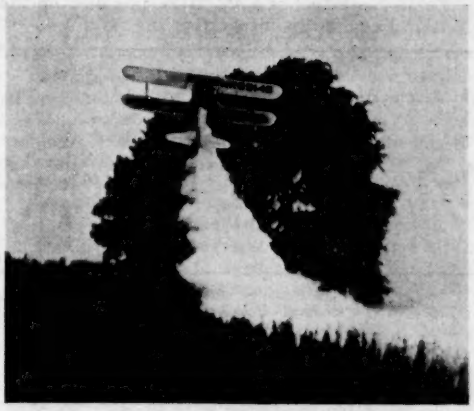

FIG. 2.—Application of 3 per cent DDT dust on 1-year old nursery stock.

In 1946 injury was quite common on Malling apple seedlings and one- and two-year old stock in western New York. Overwintering adults, young nymphs and evidence of feeding were observed on June 5. On this date *Spirea vanhouttei* was at or had slightly passed the stage of full bloom. By June 30 many leaves on 1-year apple terminals were badly curled and on July 15 injury was quite evident on the terminals of 2-year old trees. Adults of the first brood were quite numerous on Malling I and Malling IX seedlings as well as on 1-year budded stock on August 1. In block number 3 (Table 1) the rate of infestation of second brood nymphs and adults increased from 180 hoppers per 10 sweeps of a collecting net on August 6 to 327 hoppers per 10 sweeps on August 16. On August 21, the day previous to dusting, the rate of infestation was 320 hoppers per 10 sweeps. The proportion of adults and nymphs at various dates in relation to the application of DDT is given in table 1.

In 1946 opportunity was afforded to conduct experiments with DDT in three different blocks of apples in nursery plantings for control of the potato leafhopper. A three per cent DDT-talc dust was applied with an airplane[1] on August 6. A five-acre block of one-year old apple trees of mixed varieties was dusted at the rate of 45 pounds per acre, and a three-acre block of mixed Malling I and Malling IX seedlings at 85 pounds per acre. A three-acre block of one-year old trees of mixed varieties was treated with the same equipment on August 22 using the 3

[1] Approved by Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 757, April 28, 1948.

Table 1.—Per cent of adults and nymphs before and at intervals of 1, 2, and 14 days following treatment.

BLOCK NO.	TYPE OF STOCK	DATE APPLIED	PER CENT ADULTS				PER CENT NYMPHS			
			Before dusting	1 day	2 days	14 days	Before dusting	1 day	2 days	14 days
1	1-year buds	8- 6-46	91.2	64.2	50.0	45.0	8.8	35.8	50.0	55.0
2	Malling seed.	8- 6-46	82.4	47.0	75.0	65.5	17.6	82.4	25.0	34.5
3	1-year buds	8-21-46	48.7	4.1	45.4	100.0	51.3	48.6	54.6	0.0

Table 2.—Effect of a 3% DDT-talc dust on the apple leafhopper on apples in the nursery planting. Material applied by airplane at the rate of 45–85 pounds per acre.

Block No.	Type of Stock	Per Cent Adults Before Dusting	Date Applied	Ave. Hoppers per 10 Sweeps				Per Cent Reduction in Population		
				Before dusting	1 day	2 days	14 days	1 day	2 days	14 days
1	1-year buds	91.6	8- 6-46	180	13	0.8	66.0[1]	92.7	99.5	63.3
2	Malling seed.	82.4	8- 6-46	351	14	1.6	50.8[1]	96.0	99.5	85.5
3	1-year buds	48.7	8-22-46	320.5	10	6.1	5.5[2]	96.7	98.0	98.2

[1] Dusted with 4% nicotine by nurseryman August 21 (13th day after DDT treatment) for the control of green apple aphid.
[2] Sprayed with nicotine sulfate 1 to 800 plus wetting agent on August 31 for control of green apple aphid.

per cent DDT dust at the rate of 65 pounds per acre. Dusts were applied between 7:00 and 9:00 A.M. under favorable conditions with little or no wind present. Temperatures ranged between 65° and 75° F. Records on control are given in table 2. The data were taken on the day of treatment, the following day and two weeks later. In block number 2 counts were taken 2 hours after treatment, block No. 1, 4 hours after application and block No. 3, 6 hours after treatment. The per cent reduction in population at those intervals was 96.0, 92.7 and 96.8, respectively. Numerous adults and nymphs were observed on the ground in block No. 3, 30 minutes after dusting. As indicated in the footnotes under table 2, all blocks were treated by the nurserymen and either nicotine dust or nicotine spray for the control of the green apple aphid before the experiment was completed. However, the application was rather light and may not have seriously affected the population records taken on the fourteenth day after the DDT was applied.

As will be observed in table 2 considerable reduction in population was obtained at all dosages used. Results at the end of 24 hours were somewhat better than records taken a few hours following treatment. However, in blocks 1 and 2 at the end of 2 weeks there was a noticeable increase in infestation. As will be observed in table 1 there was a high percentage of adults present in these blocks at the time of application and only a small proportion of young nymphs. In block 3 adults and nymphs were about equally divided, suggesting that many eggs of the summer brood had already hatched and that the second brood was practically completed.

Preliminary experiments indicate that a 3-per cent DDT-talc dust, when applied by airplane at the rate of 45 pounds or more per acre, is effective against both nymphs and adults of the potato leafhopper on apple nursery stock. It should be pointed out that coverage on the under surface of the leaves was not too thorough. This fact may be reflected in the length of effectiveness of the DDT in these experiments. Further experiments with DDT, applied both by ground and aerial equipment, are needed to evaluate properly this compound for the control of the potato leafhopper on apples in the nursery planting. —5-14-48.

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A Comparison of the Toxicity of Some New Insecticides to the German Roach

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Because of lack of data on the toxicity and effectiveness of new insecticides for the control of the German roach, *Blatella germanica* L., comparative laboratory tests were made.

Materials.—The following materials were tested: commercial grade sodium fluoride, 50 per cent wettable powders of DDT and Chlordan, and two samples of hexachlorocyclohexane, *i.e.*, one a British sample containing 10 per cent gamma isomer and a similar material to that mentioned by Ivy & Ewing (1946), and the other a sample[1] containing 5 per cent gamma isomer. Magnesia talc[2] was used as the diluent for all samples.

Methods.—Two series of tests were conducted, one in which ten roaches were dusted and then transferred to a clean container; second, a container was dusted and 10 roaches placed in it for observations on effectiveness. The testing containers were made from No. 3 tin cans with celluloid retaining walls covered with a thin film of vaseline to prevent escape of the roaches. By the use of Woodbury & Barnhart's (1939) method of rearing roaches wide range in age was avoided.

A dust tower (Waters 1943) was used for applying the test insecticides. The amount of deposit on a given area was proportional to the amount of the charge, the deposit being given in micrograms of the active substance per square centimeter of surface area. In order to make the dust charge comparable in quantity in the roach and container tests, the materials used had to be diluted as shown in table 2.

The procedure for roach dusting was as follows: The dust was discharged from the gun and passed through a screen (16 mesh) into the tower through the screened container holding the roaches and the excess was drawn to the outside by means of an exhaust system connected to the bottom of the dust tower. The roaches were then removed and placed in a clean container with food and water.

When the container only was dusted, the same procedure was used as above except that immediately after the dust had been discharged from the gun into the tower a cap was placed on top of the tower and the dust allowed to settle for a period of 10 minutes. After the dust had settled, the container was removed from the tower and 10 roaches placed in it along with food and water for each replication. All tests were replicated at least seven and not more

than twenty-one times. Adult female roaches were used for all tests because of their resistance to insecticides.

In tabulating results, both dead and moribund roaches were counted. Readings were taken every 24 hours for 4 days for the hexachlorocyclohexane samples, five days for DDT and sodium fluoride and 6 days for the chlordan. Tests were considered complete when a period of 48 consecutive hours showed no additional roaches dead or moribund.

The following tables show results of the tests. The British sample of hexachlorocyclohexane was found to be inferior to the other sample tested and the results were therefore omitted. The dosage per unit area in the tables is given in micrograms of active ingredient for DDT, chlordan and sodium fluoride, and in gamma isomer content for hexachlorocyclohexane. Sodium fluoride was used as the standard for comparison. No mortality occurred in untreated checks.

Table 1.—Roaches Dusted

Material Used	Micrograms per sq./cm.	No. of Roaches	Av. Per Cent Dead or Moribund
Hexachlorocyclohexane .5% gamma isomer	0.5	80	28.7
	0.75	130	45.3
	1.0	80	92.5
10% DDT dust	15.0	80	50.0
	20.0	70	64.3
	20.5	70	90.0
5% chlordan dust	1.0	120	34.1
	2.0	120	52.5
	3.0	100	87.0
25% Sodium fluoride	104.19	100	24.0
Undiluted Sodium fluoride	148.8	150	57.3
Undiluted Sodium fluoride	223.2	140	70.0

Table 2.—Container Dusted

Material Used	Micrograms of Toxicant per sq./cm.	No. of Roaches	Average Per Cent Dead or Moribund
Hexachlorocyclohexane 0.1% gamma isomer	0.125	100	7.0
	0.25	80	69.7
	0.5	80	98.7
0.5% DDT Dust	2.0	70	30.0
	2.5	50	46.0
	3.0	70	74.3
0.5% chlordan dust	0.25	160	14.3
	0.5	210	35.2
	0.75	100	90.0
25% Sodium fluoride	30.0	100	39.0
Undiluted Sodium fluoride	40.0	100	51.0
Undiluted Sodium fluoride	50.0	100	95.0

DISCUSSION.—In the roach dusting tests the sample of hexachlorocyclohexane was the most toxic. A 0.5 per cent gamma isomer dust with a deposit of 1.0 microgram of gamma isomer per sq./cm. of surface gave a mortality of 92.5 per cent. In the same type of test, chlordan gave 87 per cent mortality when a 5.0 per cent dust was used with a deposit of 3.0 micrograms per sq./cm., DDT gave 90.0 per cent mortality when a 10.0 per cent dust was used with 25.0 micrograms per sq./cm. and sodium fluoride gave 70.0 per cent mortality with 223.2 micrograms per sq./cm. with the sodium fluoride used undiluted.

In container dusting a deposit of 0.5 micrograms per sq./cm. of a 0.1 per cent gamma isomer dust of hexachlorocyclohexane gave a mortality of 98.7 per cent; while a 0.5 per cent chlordan dust with a deposit of 0.75 micrograms per sq./cm. gave a mortality of 90.0 per cent; a 0.5 per cent DDT dust with a deposit of 3.0 micrograms per sq./cm. gave a mortality of 74.4 per cent, and 25 per cent sodium fluoride dust with a deposit of 50 micrograms per sq./cm. a 95.0 per cent mortality.

SUMMARY.—A comparison was made of the toxicity of two samples of hexachlorocyclohexane, DDT, chlordan and sodium fluoride to adult female roaches using a dust tower apparatus. The insecticides were tested on the roaches in the following ways: (1) container dusting; a container was dusted and the roaches placed in the container; (2) roach dusting: roaches dusted and then transferred to a clean container.

Using dosage as a basis for comparison the hexachlorocyclohexane sample proved to be more toxic to the German roach in all tests. In spite of its high toxicity, recommendations for its use will be restricted because of the objectionable and persistent odor. The next most toxic material was chlordan, followed by DDT and sodium fluoride, none of which have the aforementioned objectionable property.

It was not determined to what extent fumigant action played in the mortality resulting from using hexachlorocyclohexane. Because of the low deposit of active ingredient it seems safe to assume that it action as either a stomach or contact poison was more of a factor in the resulting mortality than fumigation effect.

These data also show that applications for control need only be made to places where the roaches hide or run, and that a lower dosage is required for high kill under these conditions.—2-5-48.

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Preliminary Experiments on the Control of the Leaf Miner *Liriomyza flaveola* on Asters

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In recent years the dipterous leaf miner, *Liriomyza flaveola* (Fallen),[1] has caused serious losses to field grown asters in the Los Angeles area. Nicotine and DDT have been used but have not given satis-

[1] Determined by C. T. Greene, Division of Insect Identification, Bureau of Entomology and Plant Quarantine.

factory control. In 1947 experiments were begun to determine if some of the new insecticides would be effective. Since then, Lange & Smith (1947) and Wolfenbarger (1947) have reported on the effect of chlordan, benzene hexachloride, DDT and hexaethyl tetraphosphate on *L. orbona* (Meig.) and *L. pusilla* (Meig.).

METHODS.—A series of 5 experiments was conducted extending over the period June to October, 1947. In the first experiment parts of 3 different plantings were sprayed. The remainder of each planting was left as a check. In the other experiments, randomized blocks with 3 or 4 replications were used. The plots were 4 double rows wide and 30 to 35 feet long.

Examinations to determine the control obtained were made at the time cutting began. All the larval mines in the leaves of 50 flower stems were counted in each plot, except in the fourth experiment, in which the number was 25.

Table 1.—Results of chlordan, benzene hexachloride and parathion treatments for control of *Liriomyza flaveola*. 1947 (1 spray application, 2 dust applications).

TREATMENT	ACTIVE INGREDIENT PER 100 GAL. OR PER ACRE FOR DUSTS	AVE. NO. LARVAL MINES PER STEM
Chlordan stock solution	2.25 lbs.	0.9
Chlordan 50% wettable powder	2.25	1.7
Chlordan 5% dust	7.50	1.5
Benzene hexachloride dust 0.75% gamma isomer	1.13	1.4
Parathion 20% emulsifiable	0.75	1.5
Check	—	28.6
Minimum significant difference, 1% level		5.8

The dusts were applied at weekly intervals and the sprays at 2 to 3 week intervals. The number of applications for each material depended on whether a dust or spray was used and the size of the plants at the time the treatments were begun. The dusts were applied with a wheelbarrow-type power duster having 4 outlets. Approximately 150 pounds per acre was used. The sprays were applied with a small power sprayer at approxinately 300 pounds pressure using a gun with a No. 3 disc.

MATERIALS.—The chlordan stock solution consisted of 2 parts chlordan and 1 part of a polymethylated naphthalene[2] by volume. It was used with 4 ounces of blood albumen spreader per 100 gallons. The 5 per cent chlordan dust was composed of 5.0 pounds of chlordan, 47.5 pounds of diatomaceous earth[3] and 47.5 pounds of pyrophyllite.[4] The benzene hexachloride dust contained 0.75 per cent of the gamma isomer and was composed of 15 pounds of a 5 per cent gamma concentrate, 12 pounds of diatomaceous earth and 64 pounds of pumice.[5] Two ounces of blood albumen spreader per 100 gallons was used with the 50 per cent chlordan wettable powder.[6]

[2] Velsicol AR-60—Velsicol Corp.
[3] *Celite No. 209*,—Johns-Manville Co.
[4] *Pyrolite*,—Huntley Industrial Minerals, Inc.
[5] *Frianite M3x*—California Industrial Minerals Co.

Table 2.—Results of chlordan and benzene hexachloride treatments for control of *Liriomyza flaveola*. 1947 (2 spray applications, 3 dust applications).

TREATMENT	ACTIVE INGREDIENT PER 100 GAL. OR PER ACRE FOR DUSTS	AVE. NO. LARVAL MINES PER STEM
Chlordan stock solution	2.25 lbs.	2.1
Chlordan stock solution	1.68	1.0
Chlordan 50% emulsifiable	2.25	1.1
Chlordan 50% wettable powder	2.25	1.1
Benzene hexachloride dust 0.75% gamma isomer	1.13	1.2
Check	—	9.6
Minimum significant difference, 1% level		7.4

RESULTS.—In the first experiment 2 applications of the chlordan stock solution, used at the rate of 2.25 pounds of actual chlordane per 100 gallons, gave excellent control under conditions of severe infestation. There was an average of 2.8 larval mines per stem in the treated plots and an average of 41.4 in the checks.

The results of the second, third, fourth and fifth experiments are summarized in tables 1 to 4, respectively. Analysis of variance indicated highly significant differences between the insecticide treatments and the checks, except in the fourth experiment where significant differences were not shown. In none of the experiments were significant differences between insecticide treatments indicated.

In the fourth experiment (Table 3) great variation occurred between plots of the same treatment. The presence of disease made it difficult to make accurate counts, but in any one plot the counts were fairly consistent. Only in this experiment did chlordan fail to give satisfactory control. This is believed to be due to an insufficient number of spray applications since two plots (not included in the table) sprayed with an emulsion containing 1.68 pounds of chlordan per 100 gallons also failed to show satisfactory control.

While the value for "F" in the fourth experiment was slightly below that required for significance, when the "t" test was applied a difference between chlorinated camphene and the checks was indicated. Chlorinated camphene also had the lowest average infestation and the least variation between replications. It therefore seems worthy of further testing along with parathion, which in the second experiment gave control equal to that of chlordan and benzene hexachloride.

[6] The chlordan for the chlordan stock solution was furnished by the Velsicol Corp.; the 50 per cent wettable chlordan, the chlordan 40 per cent emulsifiable and the benzene hexachloride dust concentrate by the Dow Chemical Co.; the chlordan 50 per cent emulsifiable by the R. L. Chacon Chemical Co.; the parathion (*Thiophos 3422*) 20 per cent emulsifiable and 15 per cent wettable by the American Cyanamid Co.; and the chlorinated camphene (*Toxophene*) 50 per cent emulsifiable by the Hercules Powder Co.

Table 3.—Results with chlordan, parathion and chlorinated camphene for control of *Liriomyza flaveola*. 1947 (2 applications).

TREATMENT	ACTIVE INGREDIENT PER 100 GAL.	LARVAL MINES PER STEM
Chlordan 40% emulsifiable	0.84 lbs.	16.5
Parathion 15% wettable powder	0.23	14.2
Chlorinated camphene 50% emulsifiable	1.25	9.9
Check	—	32.6

Table 4.—Results of chlordan treatments for control of *Liriomyza flaveola*. 1947. (Three applications.)

TREATMENT	ACTIVE INGREDIENT PER 100 GAL.	LARVAL MINES PER STEM
Chlordan stock solution	1.68 lbs.	0.5
Chlordan stock solution	1.12	1.6
Chlordan 50% wettable powder	1.00	1.2
Check	—	13.0
Minimum significant difference, 1% level		2.3

SUMMARY.—Chlordan sprays containing from 1.0 to 2.25 pounds of actual chlordan per 100 gallons, and a benzene hexachloride dust containing 0.75 percent of the gamma isomer applied at the rate of 1.13 pounds of the gamma isomer per acre, gave satisfactory control of the leaf miner *Liriomyza flaveola* (Fallen) on asters.

In one experiment a spray containing 0.84 pounds of chlordan per 100 gallons did not give control, but this is believed to be due to an insufficient number of spray applications.

Parathion and chlorinated camphene showed enough promise against the leaf miner to warrant further testing.—4-4-48.

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DDT, Benzene Hexachloride and Sabadilla to Control Climbing Cutworms on Peaches and Apricots

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Climbing cutworms often cause considerable loss of peaches and apricots by destroying the fruit buds shortly before or during blossom time. Since the customary methods of preventing such injury are not all that is desired, some of the new insecticides were tested in a badly infested peach orchard near Yakima, Wash., in the spring of 1947 to determine their value for this purpose. The treatments were applied on March 21 to trees in a section of the orchard where cutworms had already eaten off most of the fruit buds on several trees.

DDT, benzene hexachloride, and an activated sabadilla were each applied as a spray and as a dust. The sprays were prepared by using 1 pound of the insecticide per 100 gallons of water and were applied with a bucket pump to the trunk and crotch of the trees and to the soil for several inches about their bases using about 3 pints of spray per tree. The dusts were applied by means of a hand duster at the rate of approximately 2 to 3 ounces per tree. Either 9 or 10 trees were used for each treatment, and 10 trees were left untreated as a check. The treatments and results of the examination of the cutworms in the soil at the base of the trees 4 to 6 days after the treatments were applied are shown in table 1.

Table 1.—Effectiveness of DDT, benzene hexachloride, and sabadilla against climbing cutworms on peaches and apricots.

TREATMENT	CUTWORMS	
	Examined	Dead
	Number	*Per Cent*
Sprays:		
DDT	169	89
Benzene hexachloride, 7.5% gamma	97	17
Sabadilla	121	12
Dusts:		
DDT, 6%	172	95
Benzene hexachloride, 7.5% gamma	92	95
Sabadilla, 10%	186	43
Check, untreated	127	0

The results indicate that DDT sprays and DDT and benzene hexachloride dists may be used effectively to reduce the population level of climbing cutworms in peach orchards. Benzene hexachloride as a spray and sabadilla as a spray or dust were ineffective at the rates at which they were used. The small number of worms found beneath the trees treated with benzene hexachloride as compared with the numbers found under trees treated with the other insecticides and the checks may be an indication that this material had some repellent effect.

In addition to the trees treated with the sprays and dusts, 10 adjoining trees were provided with an adhesive barrier applied to the trunks on March 22. A number of trees, similarly banded by the grower several days earlier, showed some benefit from such a treatment. Only 59 worms, none of which was dead, were found beneath the banded trees when they were examined along with the sprayed and dusted ones. The much smaller number of worms found beneath the banded trees as compared with others would seem to indicate that the presence of the adhesive barrier definitely caused many of the cutworms to leave, evidently in search of food elsewhere.

The best time for application and the proper quantities of materials to use have not yet been worked out. Nevertheless, as a result of the preliminary test, DDT dust has come into general use for climbing cutworm control in peach and apricot orchards in the Yakima and Wenatchee fruit districts of Washington.—3-13-48.

A Hopper and Emission Apparatus for Distribution of Grasshopper Baits from an Airplane

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Application of poisoned baits for control of grasshoppers using a carrier of bran and sawdust (Ford & Larrimer 1921), has been carried out extensively in recent years with the aid of aircraft. For this purpose it has been customary to employ the open-cockpit types of aircraft that have been developed for crop dusting, such as the Cub, Moth, Stearman and White Standard models. The bait is carried in a hopper fitted into the space normally occupied by the front cockpit. Emission by gravity is accomplished by means of an adjustable shutter, and may be regulated by delivery of the bait on to a belt conveyor operated by an outboard propeller (Husman 1943). The mass of bait in the hopper may be agitated, or may be carried downward to the emission aperture, by means of paddles or worm gears also actuated by an outboard propeller. Application of the bait has been made by flying at low level with a view to applying the bait on the ground directly beneath the aircraft, thus producing a swath of about 15 yards width. The low capacity of these aircraft has necessitated the greater part of the flying day being consumed by reloading operations.

The aircraft employed in the installation to be described below is a single-engined, cabin, high-wing monoplane.[1] The hopper is mounted within the fuselage and can be loaded with bait while in flight. The aircraft carries 1000 lbs. of bait and has considerable cruising range and climbing power to spare. The specially designed hopper, described below, represents a new departure in that no moving parts are required to agitate or deliver the bait. Instead, the bait is agitated and its emission facilitated by bringing the suction of the slipstream into the hopper itself by means of perforated double walls. This design of hopper has given a reasonably regular emission of oil-base and freshly-made water-base baits. Application of the bait has been made from altitudes in excess of 80 feet, thus utilizing the cross-wind component to yield effective swath widths of 50 to 100 yards. In this way advantage has been taken of the greater capacity and emission rate of the aircraft in order to effect economy in the number of flights required to treat a given area.

Using this hopper and upper container, the aircraft was found to be able to carry loads of 1000 lbs. of bait and perform a baiting programme at distances in excess of 100 miles from its base, staying in the air for at least 4 hours. The bait was stored in the fuselage in bags of 40 lbs. each, and the hopper was loaded while in flight with the amounts required for the experiments. The air-crew consisted of 3 members, pilot, co-pilot and hopper operator.

THE HOPPER.—the general structural design of the hopper resembled very closely that described by Husman (1943). Essentially it consists of an open bin 26 inches deep vertically, whose forward side slopes at an angle of 42 degrees with the vertical, the rearward side at 25 degrees, and the two lateral sides at an angle of 13 degrees with the vertical (Fig. 1). It measures 40 inches long by 30 inches wide at the top, tapering down to the following dimensions at the base: 11.25 inches long by 19.25 inches wide. It is either closed by a centrally hinged lid or topped by an upper container (see below). It will hold 200 lbs. of oil-base bait.

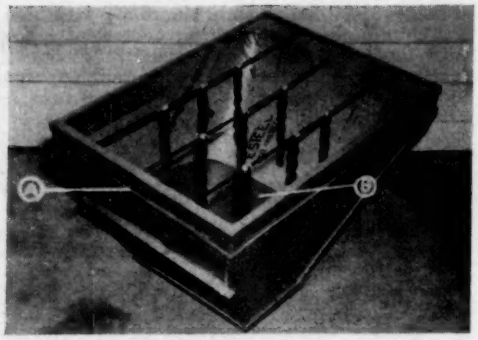

FIG. 1.—The hopper showing (A) Air inlet holes at top of rearward side and (B) Perforated lower section of false wall.

The hopper is constructed throughout of sheet aluminum (Dural) .043 inches thick. All joints are lapped and the joints and reinforcing are riveted. The base rests on the floor of the aircraft fuselage, and the forward side is braced to it by a pair of struts. The upper 4.5 inches of the sides are vertical. A 1.5 inch flange at the base, on which the emission chute sits, reduces the dimensions to 8.25 inches by 17.25 inches. Three longitudinal bars each supporting 3 lengths of iron logging chain varying in length from 1 to 2 feet, dangle in the body of the hopper to prevent packing of bait.

It is mounted in the rear of the fuselage of the aircraft, so that the base is approximately 1 foot forward of the mid-point of the side (freight-loading) doors of the cabin. This position is directly above the fourth floor bay to rear of the first vertical main member of the fuselage (the rearmost bay with A-type bracing). The emission pipe leading vertically downwards from the base passes through the third fairing former, which was cut to accommodate it; and a crosspiece member was inserted in the A to support its rearward side and a longitudinal piece to abut against its forward side.

THE CHUTE AND SHUTTERS.—The emission chute consists of a square pipe, measuring 8 inches by 17 inches (Fig. 2). It is 20 inches high, projecting 1.75 inches below the external surface of the fuselage. An attachment increasing the forward length (slipstream side) by 3.75 inches, and tapering back and up to meet the bottom of the rearward side, was added to prevent turbulence forcing its way back into the chute (this is not shown in the figure).

The horizontal shutter is inserted 4 inches below the top of the chute, *i.e.*, the floor level of the fuselage. It consists of a sheet of 0.25-inch molded laminated plastic[2] 9.5 inches long by 16.75 inches wide, whose butting edge at the emission aperture, which faces forward in the aircraft, is cut away on the underside at an angle of 45 degrees. Its sides slide between two 0.75-inch aluminum angles, and the butting edge rests on a half-inch projection. Thus the clear opening at the adjustable side is reduced to 7.5 inches by 14.75 inches.

Two arms attached to the rearward edge of the bakelite shutter are connected by a pivoted linkage to a hand lever mounted on a quadrant set on the floor of the fuselage. The periphery of the quadrant

[1] *Noorduyn Norseman Mk. IV (C-64*

[2] *Micarta bakelite*, made by Westinghouse Electric Mfg. Co., Pittsburgh. See their Data Book B-3184 for details.

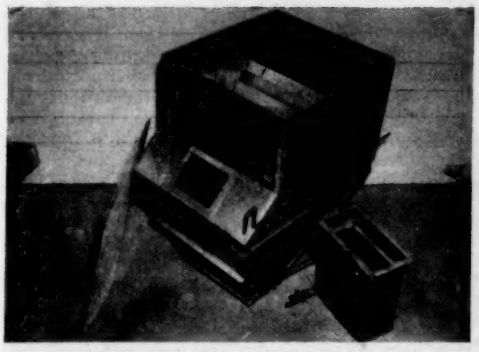

FIG. 2.—The hopper complete with upper container and the chute and shutter.

is graduated to correspond to the number of inches of opening of the aperture. An adjustable stop is provided to allow the lever to be pushed to a set aperture opening.

AIR CIRCULATION.—In preliminary trials with the original hopper closed by a lid, it was noted that when the emission shutter was opened while the aircraft was in flight at 120 miles per hour there was a considerable degree of suction pulling down on the lid. This suction was utilized by boring holes in the upper (vertical) part of the forward and rearward sides of the hopper, and bringing the air to the hopper contents by means of inserting a false inner wall whose lower half was made of perforated metal.

Groups of 7 air inlet holes, each 0.875 inch in diameter, were bored in the forward and rearward sides. The false inner wall was constructed of 26-gauge galvanized iron, spaced an average of 2 inches away from the true wall. The lower portion, up to the 13-inch level, consisted of perforated metal containing 144 holes (0.042 inch in diameter)per square inch. Two wall units were employed, one for the forward wall, and a single shaped unit for the sides and forward wall together, shaped much like the end of a bath-tub. Thus all angles and flanges were avoided.

An adjustable closure slide was provided over the air inlet holes to regulate the degree of suction. The effect of this air circulatory system was to render the bait particles in the lower half of the hopper almost entirely airborne when the emission shutter was open. The contents of the upper part of the hopper would progressively fall and become part of this whirling mass.

THE UPPER CONTAINER.—In order to provide additional capacity, and incidentally a means of loading which would avoid packing, a second container was constructed to fit on the top of the hopper, extending as high as the roof of the fuselage would allow (Fig. 2). Its total height is 22.5 inches, and it measures 33.5 inches long by 30.5 inches wide at the top.

At a level 7.5 inches above the hopper, a set of 7 shutters was constructed, running across the width of the upper container to form a floor. They were linked together on the outside so as to be opened and closed simultaneously by a push-and-pull lever. Below the level of the shutters the forward side of the container was carried forward to fit the 41-inch length of the hopper, and in the oblique wall so formed there was inserted a 7 inch by 10 inch plastic window through which the rate of expenditure of the charging could be watched.

The upper container is filled by opening a door on the forward vertical side, covering an opening which measures 24.5 inches wide by 11.5 inches high. This door opens upwards and may be hooked on the roof of the fuselage. First the hopper below is loaded by successively filling the bulkhead and opening the shutters, thus giving a gentle fall to the bait and eliminating packing in the hopper. When the hopper is filled, an additional 100 lbs. may be put in the upper container and the door closed. As soon as the hopper charging is seen to be half expended, the shutters may be opened and the contents of the upper container may thus be added.

EMISSION RATE.—Data obtained from 10 assessment flights with oil baits (containing 55 lbs. of oil per 100 lbs. wheat bran and 200 lbs. sawdust) indicated that the following delivery rates may be obtained at the folllowing aperture widths of the emission chute: 7 to 9 lbs. per second at 1.5 inches, 12 to 15 lbs. per second at 2.0 inches, and 15 to 20 lbs. per second at 2.5 inches. Settings of 1 inch and less of aperture are inadvisable since they result in very irregular emissions.

Data obtained from 4 assessment flights with water-base baits (47 to 60 per cent moisture content in bran-sawdust) gave the values of 6 to 8 lbs. per second for 1.5 inches aperture and 12 to 16 lbs. per second for 2.5 inches aperture. Emission of freshly made bait was satisfactory, but bait employed 4 days after mixing was found to stick in the hopper, adhering in masses measuring up to 3 inches in diameter.

SUMMARY.—A hopper for distributing grasshopper bait from aircraft is described, which utilizes the suction of the slipstream to facilitate emission, and does not require mechanical devices for agitation and delivery regulation. It will deliver oil-base baits at approximately even rates, determined by the aperture opening, in the range between 7 and 20 lbs. per second. Water-base baits may be similarly handled only if freshly made.

The hopper is mounted in the fuselage, and may be filled while in flight. One thousand pounds of bait may be thus applied at distances in excess of 100 miles from base.

ACKNOWLEDGEMENTS.—The hopper was constructed by No. 10 Repair Depot, R.C.A.F., Calgary, Alberta, to designs drawn up by Lt. I. C. Scarlett, R.C.E.M.E. The authors are indebted to Mr. Melrose Carberry, Carberry Crop Dusters, Fresno, California, for valuable advice in the initial stage of this project.

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A Back-Pack Fog Gun for 2,4-D Application

WM. S. STEWART[1] and CYRIL GAMMON[2]

During the past year, in conjunction with the California State Bureau of Entomology and Plant Quarantine project for eradication of the western grape skeletonizer, *Harrisina brillans*, in San Diego County, the students of entomology and plant physiology (University of California Citrus Experiment Station) worked closely together.

The larvae of this skeletonizer feed on the leaves and fruit of both cultivated and wild grapes.

Although this newly arrived insect in vineyards in San Diego County, California, may be controlled by insecticides, it seemed advisable to attempt to prevent its outward migration by eradicating its natural breeding place on the wild grapes.

After preliminary trials with most of the recognized herbicides, the well-known herbicide 2, 4-D was found to be the most promising. Application of 2, 4-D presented a problem, however, as the majority of the grapevines were in very inaccessible canyons, and because of the extremely rugged terrain could be reached only on foot. These conditions restricted application methods to readily portable equipment and for the most part eliminated the use of water sprays containing low concentrations of 2, 4-D (.05 to .10 per cent).

It has been known for some time that aerosol application of 2, 4-D and other chemical plant growth regulators is more effective for certain purposes than other means of application. The usual aerosol bombs, however, must be recharged with gas, usually from a heavy cylinder. The bombs are also limited in both capacity and concentration of chemical they may contain. These factors eliminated their use for this eradication project.

The advantages of aerosol application, with none of the disadvantages, were obtained, however, by "borrowing" from the field of entomology the portable fog gun. This type of machine has been used by household pest control operators for DDT application during the past three years. It consists of a steel cyclinder which is closed at the ends and has a free moving piston. On one side of the piston the cylinder is charged with nitrogen gas at 350 pounds per square inch. This is done at the factory and needs no further attention. On the other side of the piston the cylinder is premanently connected to a lightweight hydraulic hand pump. The solution to be dispensed is pumped into the cylinder to a pressure of 1000 pounds per square inch against the nitrogen. Appropriate check valves prevent its flow back through the pump. The portion of the cylinder containing the liquid is connected directly to a core type atomizing nozzle by means of a flexible high pressure hose. Opening the hand valve in the hose line allows the solution in the cylinder to escape through the nozzle. Even at the lowest operating pressure (350 pounds per square inch) the nozzle produces a finely dispersed aerosol-like fog. The discharge time varies from 12 to 20 minutes depending on the viscosity and other properties of the solution. The gun used weighs 28 pounds, and may be charged with .45 gallon of solution.

The use of these guns for application of 10 per cent to 40 per cent 2, 4-D solutions on wild grapes has given a very satisfactory killing of all of the ground cover foliage up to 10 feet high. Even above this height, and as high as 40 feet, killing often occurred. Variation in killing of the higher portions of the vines apparently depended on wind currents distributing the fog. In one canyon the characteristic 2, 4-D odor was detected more than a mile from the place it was being applied.

On other projects similar killing of other weed plants susceptible to 2, 4-D was obtained by this type of fog application. As on the wild grape plants, 2, 4-D was applied at concentrations of from 10 to 40 per cent. At these high concentrations no differences were observed in the killing efficiency of the various salts and esters of 2, 4-D or in their application in oil or water. It was observed, however, that a light petroleum oil produced a finer mist of fog but was no more effective against grape than a water solution at the concentration of 2, 4-D used.

Fog applications of 2, 4-D as made in experimental studies on grape eradication from June to September killed few if any leaves on wild blackberry, wild rose, live oak, buckwheat, and *Baccharis* sp. Mature leaves on sycamore and poison oak were only moderately affected. Alder, willow, California black walnut, ragweed, and *Artemisia* sp. were killed. Killing of alder and black walnut, as with poison oak, seemed to depend on various factors, such as leaf maturity, plant size, and coverage.

The high degree of portability of the fog gun suggests its use for 2, 4-D weed control in drainage canals, marshes, meadows, and other sites not accessible to heavier equipment or some distance from a water source. The fog method of 2, 4-D application should be used with caution where drift would injure valuable plants.

Close cooperation and integration of the various specialized branches of agricultural research is becoming increasingly important. In helping to solve the wild grape plant eradication problem it is interesting that entomological apparatus was adapted to plant physiological work for entomological purposes. Integration of research in entomology and plant physiology resulted in mutual benefits.

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Laboratory Tests of N-Substituted *m*-Nitrobenzamides against the Codling Moth

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The toxicity under laboratory conditions of certain N-substituted *m*-nitrobenzamides to newly hatched larvae of the codling moth, *Carpocapsa pomonella* (L.), is recorded in this paper.

N-substituted *m*-nitrobenzamides were prepared by reacting m-nitrobenzoyl chloride with various amines under suitable conditions, according to the following equation:

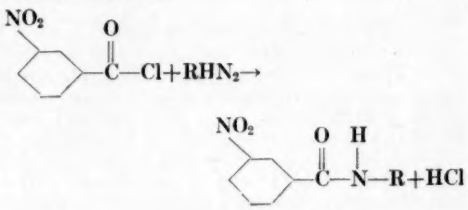
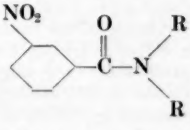


Table 1.—Toxicity of some N-substituted *m*-nitrobenzamides to codling moth larvae.

NAME OF COMPOUND	FORMULA	PERCENTAGE OF APPLE PLUGS	
		WORMY	STUNG
1-(*m*-Nitrobenzoyl)-2-phenylhydrazine	$C_6H_4NO_2CONHNHC_6H_5$	62	4
4-(*m*-Nitrobenzoyl) morpholine	$C_6H_4NO_2CON(CH_2)_2O(CH_2)_2$	64	7
N,N-Diisopropyl-*m*-nitrobenzamide	$C_6H_4NO_2CON[CH(CH_3)_2]_2$	65	0
m-Nitrobenzanilide	$C_6H_4NO_2CONHC_6H_5$	67	4
N-sec-Butyl-*m*-nitrobenzamide	$C_6H_4NO_2CONHCH(CH_3)C_2H_5$	72	8
N-Cyclohexyl-*m*-nitrobenzamide	$C_6H_4NO_2CONHC_6H_{11}$	72	10
2′-Chloro-3-nitrobenzanilide	$C_6H_4NO_2CONHC_6H_4Cl$	73	5
N,N-Dicyclohexyl-*m*-nitrobenzamide	$C_6H_4NO_2CON(C_6H_{11})_2$	76	4
1-(*m*-Nitrobenzoyl)piperidine	$C_6H_4NO_2CON(CH_2(CH_2)_4N)$	80	0
3′-Chloro-3-nitrobenzanilide	$C_6H_4NO_2CONHC_6H_4Cl$	81	2
N-Isobutyl-*m*-nitrobenzamide	$C_6H_4NO_2CONHCH_2CH(CH_3)_2$	81	7
m-Nitro-N-propylbenzamide	$C_6H_4NO_2CONHC_3H_7$	82	0
N-Isopropyl-*m*-nitrobenzamide	$C_6H_4NO_2CONHCH(CH_3)_2$	82	6
N-Amyl-*m*-nitrobenzamide	$C_6H_4NO_2CONHC_5H_{11}$	84	1
N-Butyl-*m*-nitrobenzamide	$C_6H_4NO_2CONHC_4H_9$	85	5
N-Methyl-*m*-nitrobenzamide	$C_6H_4NO_2CONHCH_3$	89	0
N,N-Dimethyl-*m*-nitrobenzamide	$C_6H_4NO_2CON(CH_3)_2$	96	0
DDT 1 lb. per 100 gal. (Avg. of 4 tests)	—	4	4
DDT ¼ lb. per 100 gal.	—	27	9
Lead arsenate 4 lb. per 100 gal. (Avg. of 4 tests)	—	44	12
Check (Avg. of 5 tests)	—	90	2

This represents the general equation. Where secondary amines were used, the resulting compound is represented by



R may be an aliphatic or aromatic radical. In the case of heterocyclic compounds with nitrogen in the ring, the nitrogen is linked directly to the —C=O.

All insecticide tests were made by the apple-plug method, a single ready-to-hatch codling moth egg being used for each plug. From 82 to 108 plugs were used for tests of the amides, 41 to 106 for DDT, 91 to 99 for lead arsenate, and 89 to 104 for the checks.

The carrier for all tests was 20 per cent ethanol. The amides and lead arsenate were tested at a concentration of 4 pounds per 100 gallons of the carrier. DDT was tested at 1 pound and 0.25 pound per 100 gallons of carrier.

The results of the tests are recorded in table 1. It will be noted that none of the amides indicated promise when compared with DDT.—4-24-48.

Field Applications to Control Spittle Bugs in Michigan[1]

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Severe spittle bug infestations on such perennial crop plants as strawberries and field legumes have caused increasing concern among Michigan growers. On these crops, varieties of the meadow spittle bug, *Philaenus leucophthalmus* (L.,) have caused considerable injury. In addition, the presence of the spittle has frequently caused dissatisfaction on the part of strawberry pickers. The injuries caused by this species have been recorded by Mundinger (1946), Fisher & Allen (1946), and Scholl & Medler (1947). The discussion in this paper will be confined to the control of the nymphal stages of the insect.

On strawberries, rotenone sprays and dusts have been used with variable success by growers. When applications were thorough and environmental conditions, especially temperature, were favorable, the results were usually fairly satisfactory. There have been enough failures with rotenone treatments, however, to warrant a search for a more effective control.

A series of plots in a strawberry planting in southwestern Michigan was sprayed on May 22, 1947, with the formulations listed in table 1. Sprays were applied with an orchard sprayer equipped with a 12 foot horizontal weed boom. The boom had twelve nozzles with 0.05 inch weed discs. These discs produce a fan-shaped spray which was directed at right angles to the sprayed plants at approximately 500 pounds pressure. When moving at the rate of about 2 miles per hour and covering three rows, the output of the sprayer was approximately 450 gallons per acre. The applications were made on a clear day with a temperature of 65 to 70° F. and a moderate southwest wind. Coverage appeared to be thorough. Most of the nymphs were located down in the crowns of the plants where it is difficult to hit them directly with sprays. The abundant mulch, which is customarily used on strawberries, affords additional protection to the insects from sprays.

The test plots included three rows 85 feet in length. Check areas included three rows on both sides of the test plots. When counts were made 5 days after treatment, 100 plants from each of the test plots and from 23 locations in the check areas were

[1] Published by permission of the Director of the Michigan Agricultural Experiment Station. Journal Article No. 928 (N.S.)

Table 1.—Results of spraying strawberries —1947.

TREATMENT: MATERIALS PER HUNDRED GALLONS	AVERAGE PER CENT OF PLANTS INFESTED IN THREE REPLICATED PLOTS 5 DAYS AFTER TREATMENT	PER CENT OF REDUCTION FROM AVERAGE OF ALL CHECKS
Rotenone (4.8%) 3.25 lbs. and 3 oz. spreader	16	70.9
DDT (50% wettable) 1.5 lbs.	24	56.4
Fixed Nicotine[1] 3 lbs. plus DDT (50% wettable) 1.5 lbs.	29	47.3
Hexaethyl tetraphosphate 1 pint plus 1 quart of summer oil	40	27.3
Benzene hexachloride (6% gamma isomer), 3 lbs.	0.00	100
1.5 lbs.	0.00	100
Nicotine sulfate (40%) 1 pint plus 2 lbs. hydrated[2] lime and 3 oz. spreader	9	83.6
Nicotine sulfate (40%) 1 qt. plus 2 lbs. hydrated[2] lime and 3 oz. spreader	18	67.3
Untreated checks	55[3]	—

[1] *Black-Leaf 155.*
[2] This represents average of 23 check plots (2300 plants) examined.
[3] Triton 1956.

examined. An infested plant, as referred to in table 1, represents any plant with one or more live nymphs.

There was but slight variance in the percentage of infestation in the different check locations except for those closely adjacent to plots sprayed with benzene hexachloride. These checks, adjacent to the plots treated with benzene hexachloride, showed an infestation of less than one-third of the average of all other checks. It was not observed at the time of spraying that these rows were hit to any extent by the spray drift.

The possibility that the berries might be tainted by benzene hexachloride was a matter of some concern. However, the musty odor associated with this material was almost impossible to detect at the time these counts were made (5 days after treatment). Subsequent palatability tests on fresh and cooked strawberries which had been sprayed or dusted not later than a week before harvest failed to disclose objectionable taste or odor.

Because of the apparent discrepancy in the results with nicotine sulfate, these two treatments were repeated. This showed the less concentrated dosage to be no better than the other. The likely explanation for first results (as show in the table) is that small amounts of benzene hexachloride remained in the sprayer and contaminated the weaker of the two nicotine sulfate treatments.

Following these tests on strawberries, spray applications were made on alfalfa in central Michigan on June 11, 1947. The nymphs had been active for about 3 weeks at the time of treatment. The field selected did not contain a pure alfalfa stand (see note under table 2), but it showed a high infestation of spittle bug nymphs which afforded a suitable test for the toxicity of benzene hexachloride to this insect on alfalfa. Applications were made with an orchard sprayer of 65 gallons per minute capacity, operating at approximately 700 pounds pressure, equipped with a 20 foot vertical orchard mast which bore 12 nozzles with discs that varied from No. 5 to No. 12. The mast produced a drifting spray which wetted the plants for a distance of 150 feet when sprayed to the leeward. A light wind was blowing. The plants in the first 100 feet from the sprayer received a thorough wetting. Beyond 150 feet there was little or no wetting of the foliage. Counts taken from 225 to 275 feet from the sprayer (same as Check No. 2 in table 2) indicate that the drift was too light to affect the infestation noticeably.

Table 2.—Results of sprays on alfalfa—1947.

TREATMENT	PER CENT OF STEMS INFESTED—DAYS AFTER TREATMENT	HAY YIELD[1] LBS OF DRY WEIGHT PER ACRE	INCREASE OVER CHECK
Untreated check No. 1	88%	4644	—
Benzene hexachloride (6% gamma isomer) 2.4 lbs. per acre	0.00	5476	832
Benzene hexachloride 1.2 lbs. per acre	0.2	5316	672
Untreated check No. 2	92	—	—

[1] Alfalfa made up only 60% of dry weight. The remaining 40% consisted mainly of timothy.

The rates of application for the two dosages listed in the table were 60 and 120 gallons per acre, while using two pounds of 50 per cent wettable benzene hexachloride (6 per cent gamma isomer) per hundred gallons.

Examination of individual stems, rather than the entire plant, was the method used in making the counts. The percentages given are based on the examination of 500 stems in each plot. Samples in the test plots were taken out to the 150 foot mark; this made each test plot 150 feet square.

Yields indicated were taken 4 weeks after treatments. The dry hay weights were obtained by weighing the freshly cut hay from the plots and then correlating these raw weights with those of small samples which were processed in a mechanical drier.

There was no evidence of the musty odor of benzene hexachloride, either in freshly cut or dried hay.

A series of treatments on mammoth clover were made in late June of 1947 at about the time the first adults were emerging. These treatments were designed as a test of various insecticides against insects affecting seed production; they were not intended as a specific test against spittle bugs. An eighteen nozzle power duster, equipped with a 20 foot boom, was used to apply the dusts on plots approximately one acre in area. The results are shown in table 3.

Table 3.—Results of dusting of mammoth clover—1947.

TREATMENT: 30 LBS. OF PYROPHYLLITE BASE DUST PER ACRE	PER CENT OF STEMS INFESTED 7 DAYS AFTER TREATMENT
Untreated check No. 1	57
Chlordan 2% with DDT 3%	28
DDT 5%	42
Benzene hexachloride 0.25% gamma isomer with DDT 2.5%	4
Benzene hexachloride, 0.36% gamma isomer	0.00
Untreated check No. 2	23

SUMMARY AND CONCLUSIONS.—A number of materials were tested on strawberries, alfalfa, and clover against spittle bug nymphs. The results indicate:

1. On strawberries, 6 per cent gamma benzene hexachloride, 1.5 pounds per hundred gallons and 450 gallons per acre, gave nearly perfect control. Subsequent observations showed that even smaller dosages gave excellent control. The low percentage of infestation on untreated plants which were not hit directly by spray but which stood closely adjacent to the plots treated with benzene hexachloride suggests a marked fumigating effect. There was no evidence of tainting of the strawberries by benzene hexachloride when applications were made at least 1 week prior to harvest.

2. Rotenone (4.8 per cent) and nicotine sulfate (40 per cent) with lime applied at 3.25 pounds and 1 pint per hundred gallons, respectively, 450 gallons per acre, gave fairly good control.

3. DDT, 1.5 pounds; DDT, 1.5 pounds, with fixed nicotine, 3 pounds; hexaethyl tetraphosphate, 1 pint;—in 100 gallons of spray, each failed to provide satisfactory control when applied at the rate of 450 gallons per acre.

4. On alfalfa, 2 pounds of 6 per cent gamma benzene hexachloride per hundred gallons gave very good control at both 60 and 120 gallons per acre. This showed a 14 to 18 per cent increase in hay yield when cut four weeks after treatment.

5. On mammoth clover, 0.25 per cent and 0.36 per cent gamma benzene hexachloride applied as 30 pounds of dust per acre showed 93 per cent and 100 per cent control, respectively, of nymphs.—1-8-48

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Serological Evidence of Resistance of Larvae and Workers to *Bacillus larvae*

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This investigation was undertaken to study the possible resistance of bees to American foul brood. The fact that American foul brood, *Bacillus larvae* White, is characteristically a disease of the larvae led the authors to believe there might be some difference in degree of immunological resistance between larvae and adult bees from an infected colony.

Park (1937) showed some bee colonies are resistant to American foul brood. He suggested that resistance might be a combination of behavioristic and physiological characteristics. Woodrow (1941) found brood of so-called "disease resistant" bees no more resistant to American foul brood than brood of highly susceptible colonies. He suggested that colony resistance depends upon behavior rather than physiological factors. The escape of part of the brood from infection appears to be a result of the short period in larval life, during which inoculation must occur to produce infection; and to the type of food material fed at the time, e.g. Royal jelly, beebread, etc. In a highly infected colony, this chance of escaping infection would appear to be slight.

The presence of disease resistance mechanisms in insect blood was reported by Glaser (1918) and Zernoff (1931). Glaser demonstrated specific agglutinins for *Bacillus poncei* in immune blood of the red-legged grasshopper, *Melanoplus femurrubrum*. Zernoff found non-specific bacteriolysins in blood of the wax moth caterpillar, *Galleria mellonella*.

EXPERIMENTAL.—A colony of bees (Italian) naturally infected with American foul brood was set up and maintained in the apiary house, N. D. A. C. Experiment Station. An entrance consisting of a piece of glass tubing, ¼′ diam.×12″, connected the hive body to a landing platform outside the building. The colony was queenless when obtained. A laying queen (Italian) was introduced and the colony proceeded "normally." This colony was the source of bees for blood.

A strain of *Bacillus larvae* was isolated from this colony and was used in parallel with another strain from old, infected combs. Both isolations were maintained in a carrot extract broth, the composition of which was based on a preparation suggested by Lockhead (1933).

The extraction of blood was undertaken in the following manner. A Wright's capillary pipette with a short needle-like end served as a hypodermic syringe. Sensitive control of incoming fluid was obtained by fastening a small screw-clamp to the rubber bulb of the pipette. An adult bee, anesthetized with carbon tetrachloride, was held with forceps to expose the dorsal side. The pipette was thrust through the integument of the mesonotum, just forward of the notal fissure. This region was chosen to lessen the possibility of contact with the larger abdominal organs.

A dissecting microscope aided in the process, since only a very small drop was obtained from each adult bee. A total of approximately 0.06 ml. was collected from 30 adult worker bees. But the extraction of the larval blood presented no difficulties. After removal of larvae from the comb cells, the cuticulum was gently punctured with a glass needle. As a drop of the body fluid collected at the wound, it was drawn into the pipette. Only the first drop was collected. All blood (adult and larval) was transferred separately to small precipitin tubes and covered with sterile seals of vaspar (vaseline-paraffin 1:1) to prevent darkening by oxidation. The tubes of blood were kept in the icebox and used the same day for the agglutination reactions.

The antigen, *Bacillus larvae*, was separated from the broth cultures by centrifugation. The cell residue was suspended in physiological saline and adjusted to a concentration of about 600 million cells/ml. by a standard nephelometric reading. This concentration was retained as standard throughout the investigation.

A strain of *Bacillus subtilis* (#133, Dept. of Bacteriology, N. D. A. C.) was used to prepare the antigen for determining the specificity of agglutination of *B. larvae* by the bee blood.

Agglutination was observed in a series of hanging-drop slides. A separate series was used for each blood sample. A primary dilution (1:5) of blood and physiological saline was prepared as follows. A grease pencil mark was made approximately 6 mm. from the end of a capillary pipette and the bee serum was drawn into the pipette up to this mark. Then air was drawn in, and then similarly, four equivalent amounts of 0.85 per cent saline separated from each other by a bubble of air. The entire amount within

the capillary was mixed, by aspiration, on a glass cover slip. The final volume of this 1:5 dilution was predetermined by trial and error. The subsequent dilutions, 1:10, 1:20, etc., were made from the primary 1:5 dilution. All slides were incubated at 37° C. for two hours and observed. They were then stored in the ice box overnight and examined the following morning. The second reading revealed no evidence of reduction in cell numbers, i.e., no evidence of bacteriolysis.

EXPERIMENTAL RESULTS.—The results of the agglutination reactions as recorded in tables 1, 2, and in figure 1, constitute one series of readings only. In figure 1, the degree of agglutination was plotted on the ordinate against the dilutions of blood on the abscissa. Point 0 represents undiluted serum plus the antigen. In the curves showing agglutination of *Bacillus larvae* significant agglutination is indicated by solid lines, non-significant agglutination by dotted lines. In all reactions observed, the control slides were negative. With the one exception stated below, the highest degree of agglutination was observed in the slides prepared from the adult bee blood.

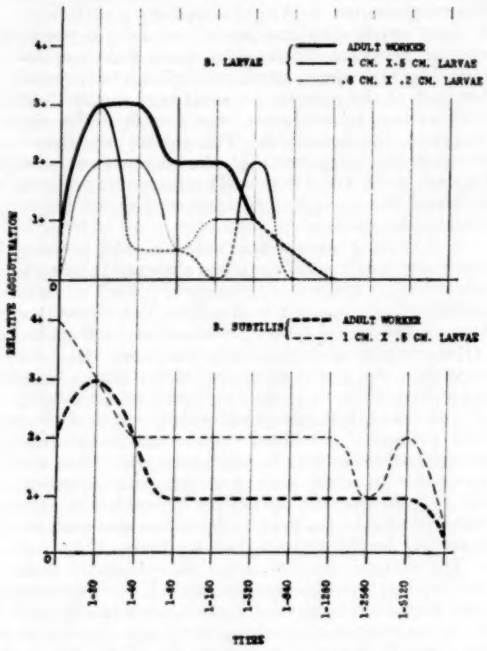

FIG. 1.—Agglutination reactions in blood of the larva and adult honeybee.

Larvae of two different stages of development, measuring 1×0.5 cm. and 0.8×0.2 cm. respectively, were examined for the presence of agglutinins. The higher degree of agglutination was demonstrated by blood of the older larvae. This suggests that there is a resistance which begins with the younger larvae and increases in degree to the adult. This is in agreement with Woodrow's findings (1941). He reported that the younger larvae were more susceptible to infection when bee colonies were mechanically inoculated with American foul brood.

Variations in amount of agglutination over a progressively increasing series of dilutions were observed. These variations, which occurred with some regularity, might be explained on the basis of inaccuracy in the high dilutions since in transferring such small amounts of liquid from one cover slip to another very small inaccuracies are greatly magnified. But in all reactions with *Bacillus larvae*, a prozoning effect was noticed. The fluctuation in positive agglutination curiously resembles the "zone phenomenon" reported by Taliaferro & Johnson (1926).

Table 1[1]

Slide No.	Final Dilution	Relative Agglutination: Adult Worker	Relative Agglutination: Larvae 1 cm ×0.5 cm.	Relative Agglutination: Larvae 0.8 cm. ×0.2 cm.
1	undiluted serum	−	−	−
2	1–20	+++	+++	++
3	1–40	+++	±	++
4	1–80	++	±	±
5	1–160	++	−	+
6	1–320	+	++	+
7	1–640	±	−	±
8	1–1280	−	−	−
9	1–2560	−	−	−
10	1–5120	−	−	−
Control	—	−	−	−

[1] *Bacillus larvae* used as antigen.

Table 2[2]

Slide No.	Final Dilution	Relative Agglutination: Adult Worker	Relative Agglutination: Larvae 1 cm.×0.5 cm.
1	undiluted serum	++	++++
2	1–20	+++	+++
3	1–40	++	++
4	1–80	+	++
5	1–160	+	++
6	1–320	+	++
7	1–640	+	++
8	1–1280	+	++
9	1–2560	+	+
10	1–5120	+	++
Control	—	−	−

[2] *Bacillus subtilis* used as antigen.

The agglutination of *Bacillus subtilis* might on first observation indicate the possibility of nonspecific agglutination of *B. larvae:* however, the over all picture observed for *B. subtilis* is different. Clumping occurred in undiluted blood (no prozoning) and at a higher degree with *B. subtilis* than it did with *B. larvae* at any dilution. Also, a higher degree of agglutination was observed for the larvae than for the adult. This adds further to the irregularity of agglutination associated with *B. subtilis.*

The nature of the agglutinate of the two organ-

isms was noticeably different, i.e., granular in the case of *Bacillus subtilis* and flocculent in the case of *B. larvae*. Extracts of the antigen, *B. larvae*, might possibly eliminate the cross-agglutination.

The authors feel that the results of this investigation are not conclusive proof that a graded immunity exists from larvae to adults in an infected colony. Similar experiments should be performed with a normal colony of bees, *i.e.*, one free from American foul brood infection. Since others have demonstrated strains of bees resistant to American foul brood, the serological reaction of the bee blood observed in this investigation is plausible. Perhaps this immunity, which can not be explained on the basis of placental immunity in higher animals, is prima-facie evidence of genetic resistance—immunity transmitted from adult queen to the egg.

SUMMARY.—A preliminary serological study was made of the resistance of larvae and adult workers to *Bacillus larvae*.

An increase in resistance from young larvae to the adult bee was found by a series of agglutination reactions.

Agglutination of *Bacillus subtilis* was also observed, but this is believed to be non-specific.

The authors feel that disease resistance in some strains of bees might well be explained on the basis of the presence of specific immune bodies in the blood.

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Notes on Biology of Cyclopic Bees[1]

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Lucas (1868) was the first to describe a young cyclopic queen. From his description it is evident that the specimen was a worker and not a queen. Dittrich (1891), besides the description of a cyclops, gives also the testimony of the beekeeper who supplied the bee. On the basis of this narrative one can assume the one-eyedness is a hereditary phenomenon, since for a number of years the daughters of the mother that produced cyclopes also produced the latter, to a lesser degree, however. The cyclopes could not fly normally. In attempting to fly they rose only about 50 cm. and then hit the ground with force, repeating such attempts over and over again. There were at times as many as 100 of them trying to fly, and "sometimes the impression was created as if somebody was throwing dry peas on frozen ground." No cyclopes were observed inside the colony. However, they probably were not expelled by the normal bees, since, when some of the cyclopes were returned to the hive normal bees did not pay any attention to them. Krancher (1919) described several specimens of cyclopic workers and drones which were found in one stock. He also noticed transitional types of these abnormalities. Alfonsus (1931) gave a thorough description of the anatomical features of a cyclops giving measurements of various parts as compared with a normal individual. He found a tuft of fine branched hair located between the bases of the antennae. However, neither he nor any of the previous investigators could find ocelli in the cyclopic bees.

Peterka (1928) first discovered that cyclopes had ocelli concealed by the lobe below the eye and above the bases of the antennae. Miller (1936) presented a histological study of the eye and brain of a cyclops and mentioned "a prominent lobe in the front between the bases of the antennae." Although he did not find any visible evidence of ocelli on the exterior of the head, the ocelli were present within the head and were complete, except for the absence of cornea. Lotmar (1936) made thorough anatomical studies of a number of cyclopic bees. She observed five main types of cyclopes. Also transitional types were present. Ocelli were found in all specimens concealed by a thick growth of hair. In the summer of 1947 Mr. M. Rockstein, a graduate student in entomology, observed an abnormal bee when he was making brain dissections. It was identified as a cyclops. Since the brood from the cyclops producing colony was used exclusively for a formation of one experimental colony and the queen from the same colony was heading another nucleus, there was a possibility of learning more about the biology of the cyclops.

The cyclopes behaved normally toward each other and toward other bees. They used antennae as any other bee and reacted to stimulation by assuming a defensive position or running away according to the circumstances. It could not be ascertained whether they fed the larvae or not. However, the pharyngeal glands located behind the upper part and on the sides of the brain were very well developed. The normal bees treated the cyclopes as any other normal member of the hive. The colony was left until all the bees died. Dead cyclopes were found during the whole period of observation, the oldest one dying at the age of at least 110 days.

Examination of the heads showed presence of a dense growth of hair directly between the eye and the bases of the antennae. These have concealed either a groove or, most frequently, a pouch-like fold or lobe with a small opening. When this opening was large enough, ocelli could be seen hidden inside. However, in the majority of cases the ocelli were concealed to such an extent that it was impossible to ascertain their presence. The dense hairs were present inside the pouch-like fold or lobe and were protruding through the opening in the latter. A few transitional types of cyclopes were also found.

Besides the cyclopes some other abnormal individuals have been found in the same colony. These were:

1. The head with holoptic eyes. The three ocelli

[1] Paper No. 2404 Scientific Journal Series, Minnesota Agricultural Experiment Station, St. Paul 1, Minnesota.

typical of the drone. The flagella with 12 joints. The mandibles larger than those of the drone, have small tooth at the end. The tongue of the drone type. The third pair of legs typical for the worker. The sting present.

2. The head with holoptic eyes. The ocelli three, as in the drone. The left flagellum with 12 joints, the right was lost. The mandibles: right-worker's, left that of the drone. The left maxilla and labial palpus are shorter than the right. Unfortunately the legs and the abdomen were lost. The tongue (ligula) is of the worker's length.
3. The head with holoptic eyes. The ocelli 3 in front somewhat distorted to the left side. The flagella 11 jointed. The mandibles, the tongue and the legs as in the worker. The sting present.
4. The head with holoptic eyes. The ocelli located as in the drone. The mandibles and the tongue are of the worker type. The flagella 11 jointed. The hind legs are one of the worker and another of the drone type. The sting present.
5. The holoptic eyes almost coalescing on the vertex. No ocelli visible. The flagella 11 jointed. The mandibles, the tongue and the hind legs are of the worker type. The sting present.
6. The eyes as in worker, coming very close together on the vertex. Two ocelli lying in the median line under almost holoptic eyes. The flagella 11 jointed. The mandibles, the tongue and the hind legs as in the worker. The sting present.
7. Holoptic eyes almost coalescing on the vertex. No ocelli visible. The flagella 11 jointed. The mandibles and the hind legs are of the worker type. The tongue is somewhat shorter than in the worker. The sting present.
8. Cyclops. Transitional type—the eye is of triangular shape.

Because of the small number of these monstrosities there was no opportunity to observe their behavior. However, Eckert (1937) reported that the monstrosities of a similar type found in a colony in California behaved as normal bees.—4-30-48.

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Buffalo of Treehopper Adults Controlled with DDT

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There has long been a need for a good spray to control the buffalo treehopper, *Ceresa bubalus* Fabr. The general recommendation, clean cultivation (Yothers, 1934) has not been satisfactory under Wisconsin conditions since many of the orchards are maintained in sod. Oil sprays have not given good control (Fluke & Gerlach, 1943), thus attempts were made in 1947 to control the treehoppers by means of DDT sprays. One application was directed at nymphs and a later one at adults.

A nymphal spray was applied to a three acre block of young apple trees in Dane County, July 21. Fifty per cent DDT wettable powder was used at the rate of 2 pounds of the powder to 100 gallons of water. The spray was applied with a 25 gallon a minute sprayer, using a single nozzle spray gun with 350 pounds pressure. One hundred gallons of spray were applied to each acre, covering the newly mowed ground cover.

An attempt was made during the following week to determine the kill of the nymphs. This was done by (1) sweeping the ground cover with an insect net and (2) by close examination of the growth between the trees. Both methods were unsuccessful, therefore the nymphal control was determined by counts of the numbers of adult hoppers that appeared later in the sprayed and unsprayed blocks. Adults did not appear until August 6 and were not numerous until August 12. One hundred sweeps of the insect net in each of the two areas on August 14 collected 45 adult hoppers in the general center of the sprayed area and 78 in the unsprayed area. A 57 per cent reduction was obtained but this was not enough for good commercial control.

Preliminary tests with DDT against the adult hoppers in cages indicated that they could be controlled with this insecticide. Therefore this same block which was used for the nymphal sprays was again sprayed August 23 just as the adults were beginning to lay eggs, using 3 pounds of 50 per cent DDT wettable powder to each 100 gallons of water,

Table 1.—Number of live adult buffalo treehoppers swept from ground cover and apple trees. Madison, Wisconsin, August 26, 1947.

Count No.	Ground Cover		Trees	
	Sprayed	Unsprayed	Sprayed	Unsprayed
1	0	1	0	18
2	0	3	0	8
3	0	0	0	2
4	0	6	0	3
5	0	3	0	7
6	0	3	0	3
7	0	8	0	1
8	0	6	0	6
9	0	1	0	3
10	0	3	0	6
Totals	0	34	0	57

applied to the young trees and the ground cover immediately under the trees.

On August 26, 3 days later, 10 counts of 10 sweeps each of the insect net in the sprayed area, going over the ground cover as well as the trees, revealed no hoppers; while in the check area 34 adults were taken from the ground cover and 57 from the trees. The counts are summarized in the table 1.

Many other counts were made on August 26 and several times during the following two weeks. Live hoppers were never taken in the sprayed area.

The fruit grower was so pleased with the results that he sprayed the remaining trees of his orchard. Again the control was practically 100 per cent effective.

SUMMARY.—DDT used at the rate of *two pounds* of the 50 per cent powder in wettable form, and applied as a ground cover spray to control nymphs of the buffalo treehopper reduced the numbers of *adults present at a later date*, but did not give practical control. When applied to trees and ground cover in late August to control adults at egg laying time, at the rate of *three pounds* wettable powder per 100 gallons, DDT was practically 100 per cent effective.

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Toxicity of Several Chlorinated Hydrocarbons to Thrips on Cotton

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Several chlorinated hydrocarbons were tested against the onion thrips, *Thrips tabaci* Lind., on seedling cotton at Bayview, Texas, in the spring of 1947.

One series of 0.1-acre plots, arranged in a randomized block with six replicates, was used. The various insecticides were applied as dusts at different strengths in pyrophyllite.

One application of dust was made on May 1 with single-nozzle rotary hand guns early in the morning, when the plants were damp with dew and the air was fairly calm. The dosage ranged from about 9 to 12 pounds per acre.

The number of adult and nymphal thrips on 50 plants per plot was determined by striking the tops of the plants across the black rubberized surface of a table and counting the dislodged insects.

The results of the tests are given in table 1.

Twenty-four hours after dusting, the reduction in the thrips population ranged from 96 to 100 per cent in all treatments.

Five days after treatment, 5 per cent chlorinated camphene was definitely superior to 5 per cent chlordan, 5 per cent DDT, or a mixture of 2.5 per cent DDT and technical benzene hexachloride containing 0.25 per cent of the gamma isomer.

At 10 pounds per acre, 5 per cent chlorinated camphene gave adequate control of the onion thrips on seedling cotton, causing reductions of 99 and 93 per cent at the end of 1 and 5 days, respectively.

[1] Acknowledgment is made of assistance given by C. A. Richmond and O. L. Walton in obtaining the field records.

[2] In cooperation with the Texas Agricultural Experiment Station.

Residual Toxicity of Hexachlorocyclohexane Incorporated in Soil[1]

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Hexachlorocyclohexane has, in the past 2 years, been tested with favorable results in the control of various soil insects, such as carrot fly, leather jacket, several species of wireworms, false wireworm, several species of white grubs, rhinoceros beetle, white fringe beetle, and southern corn root worm. With respect to residual toxicity when it is aerially applied, almost all of the references reported it to have

[1] Published with the approval of the Director as Technical Paper No. 176 of the Pineapple Research Institute, University of Hawaii.

Table 1.—Thrips infestation on seedling cotton after dusting with various insecticides, Bayview, Texas, 1947. Average of six 0.1-acre plots.

TREATMENT[1]	POUNDS OF MIXTURE PER ACRE	24 HOURS AFTER TREATMENT		5 DAYS AFTER TREATMENT	
		Thrips per 50 Plants	Per Cent Reduction	Thrips per 50 Plants	Per Cent Reduction
Chlorinated camphene—					
20%	12.3	0	100	2	99+
10%	12.0	2	99+	11	98+
5%	10.3	2	99+	74	93
DDT 5%	12.0	23	96+	256	76+
DDT 2.5% plus benzene hexachloride, gamma 0.25%	9.6	12	98	398	63+
Chlordane 5%	10.5	9	98+	309	71+
Check (no treatment)	—	712	—	1098	—
Difference required for significance, 5% level	—	124	—	94	—

[1] Pyrophyllite was used as the diluent in all treatments.

shorter persistency than DDT. Of all the references on subterraneous application available to date, only two discussed residual toxicity. Dawson *et al.* (1946) reported such a test in progress. Wallace (1946a, 1946b, 1946c), testing with the black beetle, *Heteronychus sanctae-helenae* Blanch., reported that 4.7 pounds per acre of gamma isomer in 0.78 per cent dust form and 150 to 200 gallons per acre of 0.05 per cent gamma isomer spray applied to the soil remained toxic for 4 months and 9 weeks, respectively. The test reported here was operated for a longer period, as long as 19 months, and resulted in the finding that the residual toxicity in the soil was comparable, under the given experimental conditions, with that of DDT.

Anomala orientalis Waterh., a scarabaeid, is the most injurious soil insect of pineapple plants in Hawaii. The pineapple is a long-cycle crop, extending 2.5 to 3.5 years, but the insect develops 3 or 4 generations in succession through the year in the subtropical environment. Consequently, the insect populations are usually built up to a destructive level towards the end of the crop cycle, although the initial population is usually negligible at the time of planting. Under these circumstances, only soil insecticides with a long term residual toxicity could be advantageously utilized.

Hexachlorocyclohexane containing 30 per cent gamma isomer was supplied by E. I. du Pont de Nemours & Co., and its toxicity and persistency were compared with those of DDT in pot tests. Hexachlorocyclohexane, first dissolved in xylol, was mixed into pyrophyllite dust to a strength of 3 per cent gamma isomer. DDT used was a commercially prepared 10 per cent micronized dust with a pyrophyllite base.

Double sifted clay loam soil collected from a pineapple field was mixed with various amounts of the dust in a simulated rate of 12 inches depth per acre. Such soil was placed in cans, 6.75 inches tall and 6 inches across, and garden pea seeds were planted for grub food. Five young third-instar grubs of *Anomala orientalis* per can were introduced and mortality was determined 18 to 21 days later. Four replicates of 25 grubs each in five cans per treatment were tested. DDT was tested in two series and hexachlorocyclohexane in three series; each series was provided with four replicates as check. The mortality percentage was determined by subtracting live grub numbers in the treated lot from those of the check lot, dividing by those of the check lot and multiplying by 100.

The first series of DDT was treated and first tested in July 1945, and the second series was treated in October 1945 but was not tested. Both series were stored in large cans 10 inches deep with loose lids, which were left under a glass-roofed shelter until they were tested again in March 1946. The soils were kept dry until November 1945 but moist thereafter. All the hexachlorocyclohexane series were treated and first tested in February and March 1946. All the soils with both chemicals were stored in a similar way in cans until March 1947. The soils were kept dry throughout the period. Then they were transferred to open wooden boxes 10 inches deep, which were left outdoors, without protection from rain and light, for the last six months until used in the final test in September 1947.

The results are tabulated in table 1. The residual toxicity of DDT 26 months after the application, under the given experimental conditions, was not as good as that reported by Fleming *et al.* (1947). However, that of hexachlorocyclohexane 19 months after the application was remarkably high; this is quite contrary to the findings in experiments with aerial application mentioned above. A dose of 12 pounds still gave 99 per cent kill. The data in table 1 clearly suggest that the rate of deterioration was not higher than that of DDT, although a direct comparison was impossible because of the design of the experiments.

A plant tolerance pot test with garden peas showed that hexachlorocyclohexane caused no appreciable decrease in germination up to 60 pounds per acre, but slight injury on plant growth, particularly on roots, was seen at 15 pounds and severe injury at 60 pounds.

Table 1.—Mean mortality percentage of *Anomala orientalis* at various periods after the application of DDT and hexachlorocyclohexane.

Dose/Acre[1]	Immediately After	5 Mos.	8 Mos.	19 Mos.	23 Mos.	26 Mos.
DDT						
25 lb.	91.0		86.1			40.0
50 lb.	100		95.6			50.0
100 lb.	100		97.9			75.3
25 lb.		83.7			45.8	
50 lb.		95.1			59.5	
Hexachlorocyclohexange (gamma isomer)						
0.75 lb.	44.2					
1.5 lb.	36.8					
3.0 lb.	69.5					
4.5 lb.	98.0			71.5		
7.5 lb.	100			92.0		
12.0 lb.	100			99.0		
15 lb.	100			100		
30 lb.	100			100		
60 lb.	100			100		

[1] Mixed in a simulated depth of 12 inches.

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The Publication Privilege

The question of who shall have the privilege of free publication in the JOURNAL frequently arises and has been the cause of considerable controversy. By a rule passed by the Association at the Philadelphia meeting in 1940 the privilege is limited to those who are members of the Association if such persons are professional entomologists. The publications comittee was, by the rule, permitted to grant exceptions to others if circumstances seemed to warrant such action. A professional entomologist was further defined as any person who is employed by any entomological agency, state, federal or commercial.

As a matter of standard practice exceptions have been granted to members of other professions who present papers which seem to be of greater direct interest to entomologists than to others. Usually such persons are co-authors with entomologists but they have not necessarily been so; at times independent papers have been accepted and published in the JOURNAL. It is assumed that such authors are members of their own professional groups and that they do not have any logical reason to maintain membership in the entomological organization. It is usually true also that the papers are of greater interest to entomologists than to the groups in which the authors maintain membership. A fair example of such papers might be one in which entomologists and geneticists or plant breeders have cooperated in the study of insect resistance of new varieties of plants. Such work could be a part of an insect control program but one in which the assistance of an experienced plant breeder would be essential. Other parallel situations might be cited. In the overlapping fields of plant pathology and entomology we may expect to find situations where exceptions are necessary, especially since we have the section of Plant Pest Control and Quarantine in our Association and that such work is administered through the Bureau of Entomology and Plant Quarantine. Plant Pathologists who are members of the Bureau are considered to come under the classification of entomologists and to maintain membership in our Association if they desire to use the publication privilege. Many plant pathologists, however, have no such connection and have no logical reason for supporting our Association but may have, from time to time, papers which are of direct interest to entomologists and pathologists who form our Section of Plant Pest Control and Quarantine. At the recent Chicago meetings an invitation paper was presented which will illustrate this category. The author, Dr. C. R. Orton, presented the paper by invitation. He has no direct concern with the functions of the Bureau and no logical reason to maintain membership. The paper was accepted for publication because it was obviously presented for our benefit rather than for that of the author and because it gave information available in usable form from no other source.

As a matter of fact there has been little difficulty with papers of this nature. The controversy, such as there is, has to do with papers submitted by entomologists who are not members of the Association.

The arguments which are presented to justify the rule are simple. It is recognized that our Association, in its modern form, was established with the major purpose of providing a publication outlet for its members. The great majority of the professional entomologists belong to the Association but no pressure is brought to bear on entomologists who prefer not to join. That attitude is their recognized privilege. But on the other hand, such an entomologist has no right to expect or demand that he be granted the privilege extended to members. A major part of the revenues of the Association are required to maintain the JOURNAL and JOURNAL

costs are rising rapidly. For an outsider to demand or expect the benefits provided by a cooperative enterprise in which he does not bear his fair share of the costs is entirely unreasonable. To be perfectly fair it must be stated that outsiders seldom do this; members of the Association are more likely to be the ones who demand that the publication privilege be extended to others, entomologists or otherwise, with whom they are associated.

Since this is directly contrary to the rules of the Association it is necessary to refuse such requests. And if there were no such rule it is probable that financial considerations would soon enforce such a policy on the Association. If, however, the membership desires to abolish the rule or to modify it, that is always possible. It seems probable that the matter will be discussed at the meetings in December and that the Association will either reaffirm or abolish the present rule. The JOURNAL policy will, necessarily, conform to the action of the Association. But it is desirable that the membership be informed about the present policy and the reasons for it.

It may be well to state that the rule was, by common consent, waived in many instances during the war. It was thought then that there should be no obstruction to the publication of any information which might have, directly or otherwise some bearing on the war effort.—L.M.P

Book Reviews

INSECTS OF HAWAII. By Elwood C. Zimmerman. Vol. 2: *Aperygota* to *Thysanoptera* Vol. 3: *Heteroptera*.

The Introductory volume of this work has already been reviewed in this JOURNAL. These two volumes will no doubt appeal to entomologists much more directly. Boto are beautifully printed and excellently illustrated with illustrations that are highly informative. Perhaps the greatest appeal of these two volumes to the reviewer lies in the fact that here we have for an entire region a complete treatment of all the insects known in that region.

But these volumes are vastly more than mere check lists; they are completely provided with keys to all the groups. The economic importance or particular biological interest of each group is mentioned adequately. Furthermore, the inclusion of the minor orders makes it possible for many entomologists who have not had much to do with these groups since getting into actual entomological practice, to renew their acquaintance with them.

Thysanoptera, an important economic group in the Islands, receives excellent detailed treatment and here again illustrations are so informative they are extremely valuable for species determinations.

Volume 3 treats of 224 species of *Hemiptera Heteroptera*. The volume is clearly of great value to anyone interested in the determination of these groups, the keys are numerous and adequate and as in the other volume the interesting economics and biology of the species are given considerable space.

It is true that an isolated area such as the Hawaiian Islands offers a unique opportunity for a regional entomology but it is also true that Zimmerman has set up a standard for such regional treatments that will remain a standard of excellence for a long time to come.

These two volumes can be highly recommended to anyone interested in the Hawaiian fauna, to mature entomologists who are interested in reviewing general taxonomy and especially to students. For this last group the complete treatment of all the groups of insects in a given region in relatively few pages will serve well for purposes of orientation.

Volume 2 is priced at $5.50 and Volume 3 is priced at $4.50. The complete set will be sold for $9.00.

WALTER CARTER

MANUAL OF VETERINARY CLINICAL PARASITOLOGY. By E. A. Benbrook and Margaret W. Sloss. 187 pages. Illustrated, 1948. The Iowa State College Press, Ames, Iowa. Price $4.50.

Some procedures for the diagnosis of parasitism of domestic animals are outlined. The first chapter deals with the diagnosis of internal parasites by means of fecal examination. Chapters two and three cover the mites and lice. The internal parasite ova and coccidia, mites, and lice are well illustrated by means of photomicrographic plates. Numerous references cover the subject well. This is a well organized book written for the veterinarian but will be a valuable reference for others interested in this field.

NORMAN O. OLSON D.V.M.